APPROVED: 23 June 2016

Development of probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory

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Abstract

This report demonstrates a probabilistic quantitative pathway analysis model that can be used in risk assessment for plant pest introduction into EU territory on a range of edible commodities (apples, oranges, stone fruits and wheat). Two types of model were developed: a general commodity model that simulates distribution of an imported infested/infected commodity to and within the EU from source countries by month; and a consignment model that simulates the movement and distribution of individual consignments from source countries to destinations in the EU. The general pathway model has two modules. Module 1 is a trade pathway model, with a Eurostat database of five years of monthly trade volumes for each specific commodity into the EU28 from all source countries and territories. Infestation levels based on interception records, commercial quality standards or other information determine volume of infested commodity entering and transhipped within the EU. Module 2 allocates commodity volumes to processing, retail use and waste streams and overlays the distribution onto EU NUTS2 regions based on population densities and processing unit locations. Transfer potential to domestic host crops is a function of distribution of imported infested product and area of domestic production in NUTS2 regions, pest dispersal potential, and phenology of susceptibility in domestic crops. The consignment model covers the several routes on supply chains for processing and retail use. The output of the general pathway model is a distribution of estimated volumes of infested produce by NUTS2 region across the EU28, by month or annually; this is then related to the accessible susceptible domestic crop. Risk is expressed as a potential volume of infested fruit in potential contact with an area of susceptible domestic host crop. The output of the consignment model is a volume of infested produce retained at each stage along the specific consignment trade chain.

Key words: commodity, pathway model, plant health, probability, quantitative pathway analysis, pest risk assessment

Question number: EFSA-Q-2011-00396

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Acknowledgements: Part of this project, related to trade network models, was carried out in parallel with the DROPSA project under the European Union Seventh Framework programme for research, technological development and demonstration, grant agreement number 613678. The two projects benefitted from joint consideration of commodity trade movements into and within the borders of the EU.

Suggested citation: Holt et al., 2016. Development of probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory**.** EFSA supporting publication 2016:EN-1062. 378 pp.

Summary

This report includes a comprehensive description and discussion of each of four plant product-specific quantitative models that make up the QPA Food outputs, both on a general commodity pathway and a single commodity consignment level, covering the pathways for three fruits and for wheat from any combination of external source countries to the final distribution and consumption (or waste) at NUTS2 level throughout the EU28 territory. These examples cover cases for pests of apples (from N America), oranges (from S America), stone fruits (from N America) and wheat (from Australasia/S America). All of the models have a similar structure. The three fruit models are directed to uses involving fresh consumption or processing for human consumption; the wheat model is directed at uses for direct livestock feed or for milling. There is a review and a discussion on data sources for these specific cases and the selection and extraction of plant product-specific parameter values. Sensitivity analyses are reported and research needs are discussed for each case.

This report, and four preliminary reports, are one strand of the delivery of this project. Four parameterised general pathway models and four parameterised consignment pathway models, executed in Excel spreadsheets with @Risk add-ins, have also been delivered. The general pathway models consist of two modules, a trade/infestation distribution module and a use-stream/transfer module. The consignment models each include four (fruit) or eight (wheat) trade chains relevant to different use-streams.

These models will reach their full potential through use. In the course of building, parameterising and testing the models the developers have identified a range of both forward-focussed uses in risk analysis and backward-focussed forensic analyses. The models, both at the general and consignment levels, offer opportunities for exploring scenarios related to sources, infestation levels, trade volumes, timing, distribution patterns, and use-streams, and for management measures that might be employed on commodity pathways to mitigate risks.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

This contract/grant was awarded by EFSA to:

Contractor/Beneficiary: Imperial College Consultants Ltd (ICON)

Contract/Grant title: Development of probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory

Contract/Grant number: CFT/EFSA/PLH/2011/05

1.1.1. Background

The EFSA Scientific Panel on Plant Health (hereinafter, the PLH Panel) provides independent scientific advice on the risks posed by organisms which can cause harm to plants, plant products or plant biodiversity in the European Community. The PLH Panel reviews and assesses those risks with regard to the safety and security of the food chain to assist risk managers in taking effective and timely decisions on protective measures under the Council Directive 2000/29/EC to prevent the introduction and further spread of organisms considered harmful to plants or plants products in the European Community. On request, the PLH Panel prepares and evaluates pest risk assessments and identifies and/or evaluates the effectiveness of potential risk management measures in reducing the risk of introduction and/or spread of a harmful organism. In general, these requests relate to the risk for the whole EU territory.

The probabilities of introduction and spread of plant pests may be assessed by quantitative or qualitative approaches. When a qualitative approach is followed, that may include quantitative elements. Where quantitative elements are included, transparency requires that every element of the calculation or mathematical modelling is communicated and justified, with a clear description of the model used, its accuracy and the parameter estimation. For quantitative models it is recommended to perform an uncertainty and sensitivity analysis.

Quantitative probabilistic models have been used in several instances in risk assessment to estimate the probabilities of introduction and spread of plant pests (Fowler et al., 2006; Peterson et al., 2009; Roberts et al., 1998; Stansbury et al., 2002). The PLH Panel currently applies in its opinions quantitative methods for the assessment of climate suitability for establishment and of spread of plant pests. With regard to the quantitative assessment of the probability of introduction, the PLH Panel has evaluated in 2010 a quantitative pathway analysis of the likelihood of *Tilletia indica* M. introduction into EU with importation of US wheat. This review allowed EFSA to highlight the key parameters of the quantitative pathway analysis model, identified though sensitivity analysis, but it also showed that the proposed model did not consider the possibility of introduction of the pathogen through a single infected consignment.

Probabilistic pathway analyses can be used to evaluate quantitatively the probabilities of introduction of plant pests. This method is well known in exposure assessment of the human population to chemicals (Cullen and Frey, 1999), but needs to be adapted to the specific conditions and datasets for plant health risk assessment. The production and processing of the plant product in a third country, the transportation process, the processing and marketing in the EU after importation, including the fate of its waste- and by-products, are all aspects to be considered until the final step of the transfer of the plant pest to a suitable plant host. This can be done as a global model for the whole EU with time component or as a single consignment model.

The probabilistic pathway analysis approach allows for quantitative comparison between different pathways of introduction as well as for comparison of the risk reduction effects of various risk mitigation measures along a given pathway. Moreover, though sensitivity analysis, valuable information can be obtained on major parameters affecting the probabilities of introduction of a given plant pest along a pathway. Sensitivity and uncertainty analysis may also support the identification of knowledge gaps and recommendations for future research topics.

1.1.2. Terms of reference

EFSA launched an outsourced project, through an open call, to support the PLH Panel scientific opinions by the development of probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory. The project was to be conducted using practical case studies as indicated below. The tender was divided into two Lots, one lot on quantitative analysis of pest introductions with edible plant products (Lot 1), and one lot for non-edible plant products (Lot 2). This report deals only with Lot 1 on edible plant products.

The probabilistic models for quantitative pathway analysis of plant pest introductions for the EU territory were to be developed for four case studies covering the following groups (one case study for each group) of edible plant products (for food and feed):

1. Fresh fruit: a pome fruit (apple or pear)
2. Fresh fruit: a stone fruit (apricot or cherry or nectarine or peach or plum)
3. Fresh fruit: a citrus fruit (clementine or grapefruit or lemon or lime or mandarin or sweet orange)
4. Cereals seeds for food and feed

Overall objective

To provide EFSA with probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory through the importation of edible plant products (for food and feed).

A probabilistic pathway analysis is a one-directional compartment model with stochastic transitions. This pathway model should include all treatments, transportation, processing and distribution of the plant product (including losses, waste-products and by-products) from a Third Country of origin until the final step of the transfer of the pest to a suitable plant host in the EU. The models should be generic, covering all aspects of the pathway, but with possibility of application to the different types of plant pests (e.g. viruses and virus-like organisms, bacteria, fungi, nematodes, insects and mites). The stochastic component models temporal, regional or other variations, and may also include the uncertainty of the estimated model components (parameters etc.).

Each pathway has to be modelled twice: 1) as an overall approach by a general model at EU Member States level considering the total flow in each European country on a yearly and/or monthly scale; 2) as a single consignment approach, with consideration of geographical distribution and real time scenario, following a single lot of an imported plant product and including as well the distribution of distances as the distribution of durations for transport, storage and processing.

Specific objectives

The specific objectives of the contract resulting from the present procurement procedure are as follows:

- For each of the four groups of edible plant products, the contractor should develop a generic probabilistic pathway model.
- For each of the four groups of edible plant products, the contractor should select one plant product from those listed in the description above. For each chosen plant product, plant product-specific model parameters should be identified and values assigned and a plant-product specific model should be developed. To obtain the relevant parameters, the contractor should carry out a comprehensive search of technical and scientific information and a review of data sources needed for the determination of all parameters and should discuss on the optimal selection and extraction of parameters values. For the search and review of parameters and its reporting strategy, consideration should be given to the relevant

sections of the Guidance of EFSA on the "application of systematic review methodology to food and feed safety assessments to support decision making"[1].

For each chosen plant product, one associated plant pest should be selected by the contractor, the plant pest-related and plant host-related parameters should be determined and values assigned and a final pathway analysis probabilistic model should be developed For each final pathway analysis probabilistic model a sensitivity analysis should be performed

[1] EFSA, 2010. Application of systematic review methodology to food and feed safety assessments to support decision making. EFSA Guidance for those carrying out systematic review. Available at http://www.efsa.europa.eu/en/scdocs/doc/1637.pdf.

2. Description of Models

2.1. Introduction

In Section 2 of this report, the general and consignment Excel models that make up the QPAFood outputs are described in detail, including their implementation in @RISK. This is followed in Section 3 by a comprehensive description of the information gathered about the commodities and case study pests and a description of how this was used to estimate parameter values for the models. Appendices 1-4 provide additional detail on the parameters for the four specific cases; Appendices 5 and 6 cover data sources and collection. Section 4 provides a description of sensitivity analyses carried out. Section 5 describes future research needs and Section 6 draws some general conclusions from the work.

The overall objective of the project is to provide EFSA with probabilistic models for quantitative pathway analysis of plant pest introduction for the EU territory through the importation of edible plant products (for food and feed). Four commodities and associated pests were selected for the project (Table 2.1.01).

Table 2.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities and pests

Commodity	Pest	Common name	Case study countries
Pome fruit: Fresh apples	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit: Fresh plums	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus: Sweet oranges	*Xanthomonas citri citri*	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries)
Cereals: Wheat	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

As specified in the technical specification for the project, quantitative probabilistic pathway models have been provided which follow the form of a one-directional compartment model with stochastic transitions. The models describe the transportation from source countries to, and transhipment between, EU Member States, the distribution of the plant products, the uses in retail and processing (including the associated losses, waste-products and by-products) described geographically at NUTS2, and the potential for the infestation carried on the commodity to transfer to domestic production within each MS. The models provided are generic for each commodity so that they can be used with any pest associated with the commodity, so they provide the basis for analysing all source-commodity pathways into the EU. The models presented have been parameterised for the specific pests chosen for the project. Uncertainty in model components has been incorporated by implementing the models using @RISK software, an add-in for the basic Excel spreadsheet.

The design of the models incorporates aspects of pest species risk analysis as well as pathway specific risk analysis. The distinction is that the pest specific analysis focusses on the harmful agent and the pathway analysis focusses on the route of entry and potential transfer to a host where establishment could occur. For multiple pests on a specific pathway the models would need to be run for each pest species separately (with only the pest parameters adjusted). For multiple pathways and a common pest the model could be run for the various pathways either independently by source or with groups of source countries included together.

As required in the technical specification, two model types are provided for each commodity; these are described in the report as the general models and the consignment models. The general models are models at EU Member State level that consider the total flow of a commodity from specified source countries into each European country on a monthly scale. The consignment models consider the durations for transport, storage and processing associated with each of the routes the commodity could take on entry to the EU by following a single lot of an imported plant product. Pest survival or development in the consignment is related to the duration and conditions of the stages along the specific route.

To obtain the relevant parameters and variables for both model types, a series of comprehensive searches of the technical and scientific literature were carried out to review the data sources needed for the determination of all parameters. These reviews are provided as separate appendices of the report (Appendices 1-4), one for each of the four case studies. They discuss selection and extraction of parameters and values, the results of which have been tabulated in the body of the report for each type of model for each case study. The case study Appendices inform the parameterisation of both the general and consignment models.

The general models are fully generic with respect to the commodity. All calculations are always carried out for the entire trade chain network of the commodity so that no structural changes to the models are required to use them for other pests; only the pest-specific parameters need to be changed.

The consignment models originally presented were conceived as describing particular pathways through the general model as followed by the individual consignment being considered. Those described and provided here now follow a different logic. They are generic with respect to the commodity so that only the pest-specific parameters need be changed to use them for other pests. They offer a different perspective of the problem from the general model by describing transitions between steps in the trade chain network in terms of the durations of each step and therefore the total duration to any point on the chain. The implications for the probability and the level of pest infestation at each step are calculated as with the general model.

2.2. General models

2.2.1. User Overview

Software requirements

The model requires Microsoft Excel 2010 and Palisade @Risk v6 add-in for Excel software. Please note that the model will run in Excel 2007 but some of the conditional formatting functionality may be lost; this has no effect on the output of the model.

Generality of the model structure

The structure of Apple general model is identical to that of the other fruit commodity general models, so that when a user is familiar with one model the use of the others is straightforward. The structure of the wheat general model follows a similar structure but is modified to reflect the differences in pathways, uses and losses; nevertheless when one is familiar with the fruit model then using the wheat general model will also be relatively straightforward and vice versa.

Model flow and annotation

The "Main" worksheet of the model provides an interactive flow-chart of the model's structure. Each node (button) in the flowchart is clickable to navigate to the worksheet in which the data or sub-model operates. The buttons are grouped in, conceptually related, coloured boxes and linked by arrows to show the flow of information through the model. User input cells / sheets are highlighted in pale blue, all other cells are locked to prevent accidental editing of the model structure. The model has been designed to be as self-explanatory as possible and, to this end, every worksheet in the model contains a text box description of the data/workings of that particular sheet and how it relates to other sections.

The four general models are each provided as two modules: Module 1 concerns the initial commodity infestation, import and transhipment; Module 2 concerns distribution of the infested commodity, host vulnerability and potential contact which could lead to pest transfer. The output of Module 1 is the total infested commodity arriving in each MS in each month and includes both directly imported and net transhipped volumes. When using the models, the transfer of values from the final table of Module 1 to Module 2 is achieved by browsing and selecting the required file from within Module 2.

The models were split into two modules because Module 1 contains a series of Visual Basic (VB) macros that calculate commodity movement through the trade network. These take some minutes to run but this exercise need only be carried out once for any particular set of trade data that the user wishes to use. Splitting the model into two modules makes sensitivity analysis easier because multiple sets of trade data can be stored as a series of Module 1 files without on each occasion having to run the macros to investigate a new scenario. This is useful because the VB macros which collate information from the trade databases in Module 1 are incompatible with the use of @RISK functions so it is important to provide an easily-workable approach to investigate the effects of variation in trade. The remainder of the model, contained in Module 2, does not require the use of VB macros but makes use of both direct database inputs and parameters which are described by @Risk distributions.

The models are accessed and run from a 'Main page' which also shows the model structure and sequence of calculations. All models have a similar Module 1 main page (Fig 2.2.01a); the Module 2 main pages for the three fruit cases are also the same (Fig 2.2.01b) but differ from that for wheat (Fig 2.2.01c) to reflect the different use, loss and waste streams which apply. Example main pages for the commodity, apples, are shown in Figs 2.2.01a and 2.2.01b. The complete model structure is shown on the main page of both modules. Those parts of the model structure which are not active in the particular module are indicated with pale grey text.

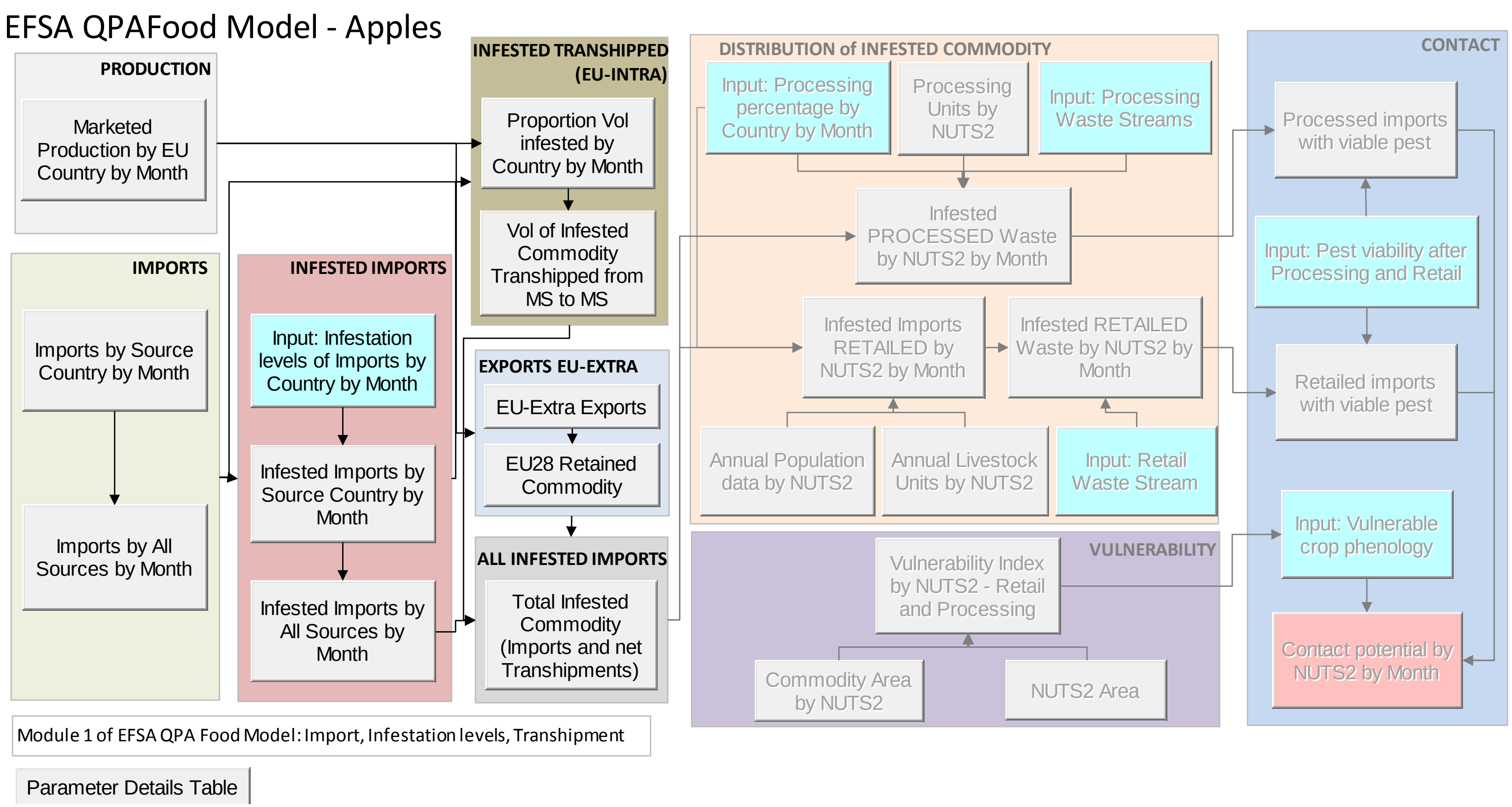


Figure 2.2.01a: The main page of the general models; a) The Module 1 main page has the same layout for all models, the example of apple is shown

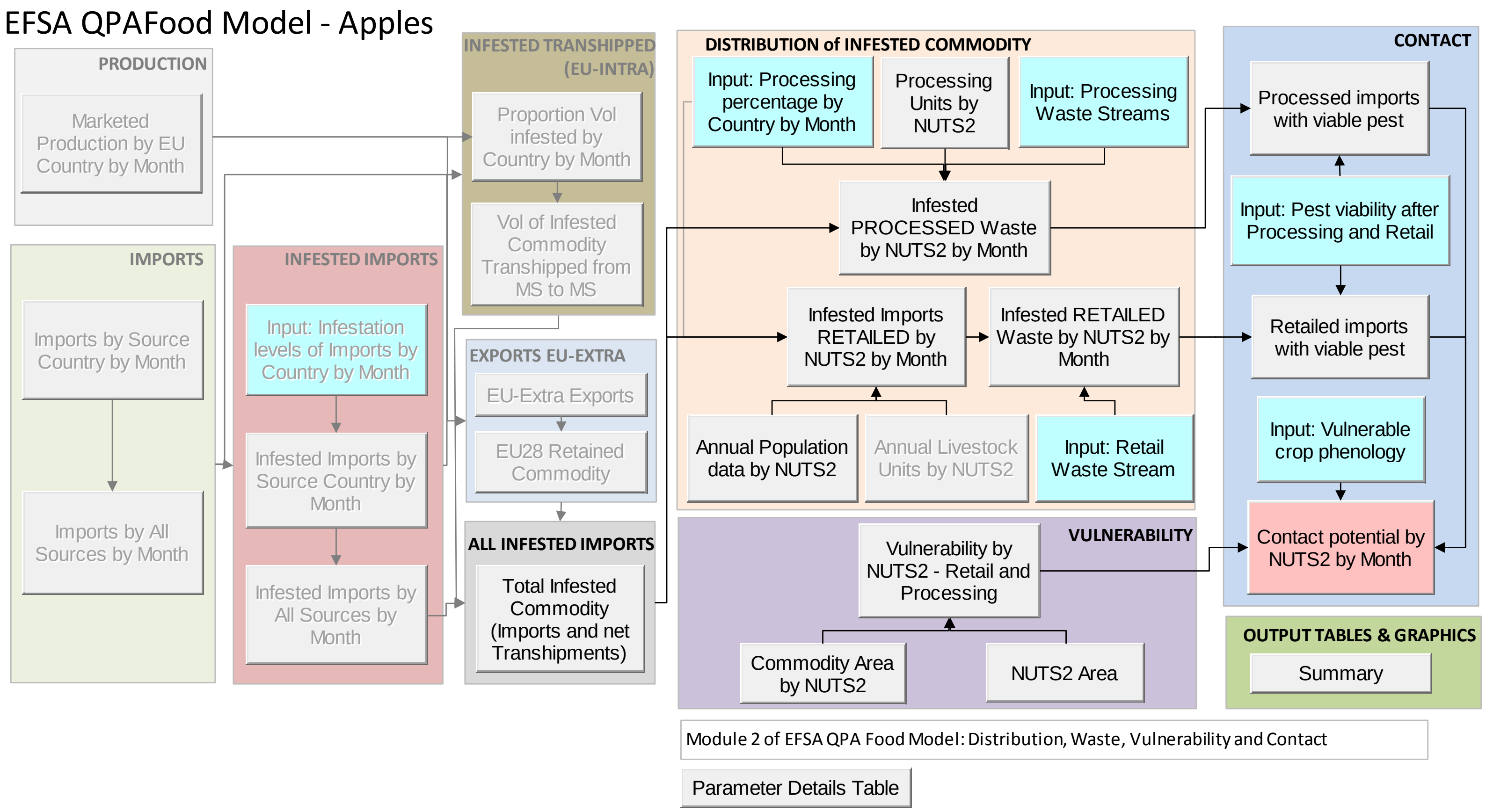


Figure 2.2.01b: The main page of the general models; b) The Module 2 main page has the same layout for all fruit models, the example of apple is shown

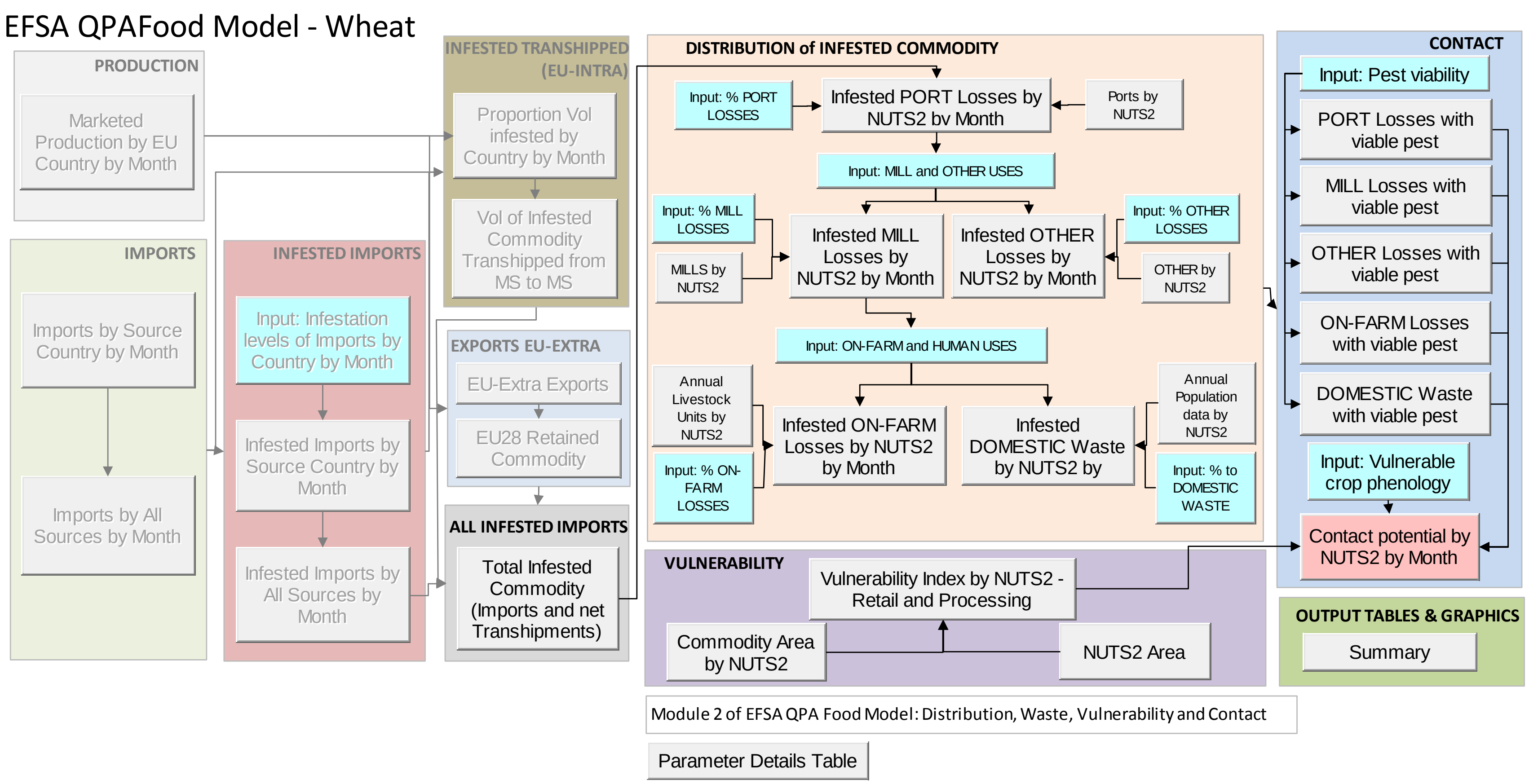


Figure 2.2.01c: The main page of the general models; c) The Module 2 main page for wheat.

A series of 'panels' are used to distinguish different parts of the model: Imports, Infestation, Distribution of Infested Commodity, Vulnerability and Contact. Within each panel, text boxes provide links to a series of sheets which contain the model variables and within which the model calculations are performed. The arrows linking the text boxes indicate the conceptual flow and the sequence of calculation. Blue buttons indicate sheets with user input options; within those sheets pale blue cells indicate potential user input points. Text boxes on each sheet with inputs give instructions on the form of input values that can be entered; error traps prevent input of invalid values. At the bottom of the main sheet there is a button that shows the overall Parameter Details Table, which describes each parameter and the values that are used.

First, the reasoning underlying the model, the model formulation and the variables are described. The description takes each panel of the model (Fig. 2.2.01), in turn.

2.2.2. Imports

The commodity import data are obtained directly from Eurostat Data Explorer databases and provide monthly trade volumes of the commodity from the 261 countries/territories of the world, as listed in the databases, to the 28 EU Member States for the years 2010 through 2014. The 261 countries include the EU28 Member States themselves, so the database also provides the means of tracking shipments of the commodity between Member States. This is important in connection with the potential transshipment of commodity from outside the EU to a final destination country within the EU via an intermediate importing country within the EU.

These trade data are contained within 261 sheets in the model (one per source country). These tables can be updated periodically directly from Eurostat. The Data Explorer database includes various aggregated regions as well as individual territories, so these must be unselected to give only the 261 distinct source countries/territories, which are then downloaded in the standard Eurostat format for inclusion in the model by pasting the Eurostat sheets. A macro is provided in the model to allow imports from all source countries to EU Member States to be collated in a single table.

For aggregated commodities in Eurostat (such as stone fruits) the annual imports to key EU countries can be drawn from more disaggregated annual data in FAOStat and the proportion for the specific commodity can be applied to monthly Eurostat values.

The databases incorporated in the general model currently give trade volumes for the most recent five years available (2010-2014) from all potential sources to all EU28 destinations. Specific sources or destinations relevant to particular pathways and pests can be examined from this complete set. Trade volumes representing alternative sets of years could be used if required.

2.2.3. Infestation

While the QPAFood model is a quantitative commodity pathway model, the pest infestation component is specific to individual pest organisms that may occur on the pathway. The model is parameterized for the source countries of the pathways relevant to the specific pest. As in the case studies, this will usually involve relatively few of the full set of 261 countries. Infestation rates of the pests are obtained from records of at-harvest infestation in the source country, detection rates at export, and survival rates under the prevailing transport conditions (Appendices 1 to 4), or using upper limits that are based on EU phytosanitary standards or commercial contract standards.

Infestation rate is measured by the units of the commodity which are infested (%). Infestation is parameterized in this way to reflect how it is recorded in plant health inspection data. There are implications for parameter units throughout the model. For direct transport to an EU Member State from a non-EU MS, the product of the trade volume (hundreds of kg) and infestation rate (%) gives the trade volume that is infested (in 100 kg units). Throughout the pathway, all potential transfer is considered in relation to infested trade volume on import, and parameter estimation is made in the context of this.

2.2.4. Transhipment

Where transport to an EU MS is via another importing intermediate EU MS, a measure of this transshipment of infested commodity to its final destination within the EU is calculated from that proportion of commodity potentially available for export in the intermediate state that has its origin in a pest-affected source country. The commodity available for export in the intermediate state includes any locally produced commodity in that state as well as that imported by that state; the sum of the two gives the total commodity available for potential export. The volume of commodity originating from pest-affected countries can be expressed as a proportion of this total. The volume of infested transshipments is then obtained by multiplying this proportion by the volume of trade in the commodity between Member States. This trade is already incorporated in the import panel (Fig. 2.2.01) and domestic production statistics of the commodity for all Member States are obtained from Eurostat. In calculating the transshipment volumes it is assumed that there is an equal likelihood of a MS exporting its own produce and produce that it has imported.

Finally in Module 1, a table of combined infested volumes which includes both direct and transshipped imports is obtained by summing the directly imported and transshipped infested volumes. The infested export volume in this calculation is deducted, otherwise the transshipped volumes would be wrongly counted as direct imports to the state of initial EU entry. This table then provides the link to Module 2.

2.2.5. Distribution of infested commodity

In the case of fruit commodities, two distribution routes for the commodity are considered, retailing of the fresh product and processing. Those types of processing which involve juicing and those which do not (e.g. dried fruit, baking ingredients) are considered separately because the nature of the waste/by-product differs. Three waste/by-product streams are modelled: whole rejected fruit (from juicing and non-juicing type of processing), peel, core and/or stone as appropriate for different fruit types (from juicing and non-juicing) and pulp/pomace (from juicing). In non-juicing types of processing, the peel, core, and/or stone may be removed initially. In juicing, the whole fruit is usually used so that peel, core and/or stone then form part of the pulp residue. In the case of oranges, peel is removed before juicing but with apples and plums it is not. The waste/by-product is destined either for animal feed (usually after further processing) or for land application (usually after composting) in proportions depending of fruit type (Appendices 1 to 3).

Waste from retailed fresh fruit is categorized more simply, being either whole rejected fruit or peel, core and/or stone, all of which are destined for land application.

This adds up to a total of twelve different combinations of possible waste streams, each with implications for pest survival and each of which is commodity specific (Fig. 2.2.02; Table 2.2.01).

The distribution of the infested commodity between commodity use, by-product type and by-product use is modelled in the series of sheets associated with the distribution of the infested commodity. Estimates of the percentage of the commodity destined for the retail and processing routes was obtained from trade sources (Appendices 1 to 3). These values are collated as a 28 EU MS x 12 month table. Values differ between countries and months to reflect any known differences; otherwise an average figure is used. For example, Hungary has a very high proportion of apple processing use and France very low. The EU average for processing apples is 25%. Estimates of by-product type were taken from various sources as described in Appendix B. The proportion of by-product destined for land application and animal feed was also obtained from industry sources (Appendix B).

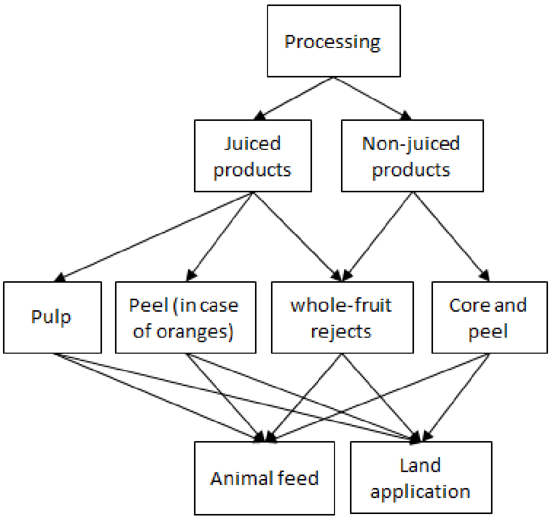


Figure 2.2.02: Structure of the processing waste streams for fruit commodities

Table 2.2.01: Twelve waste/by-product streams defined by possible combinations of commodity use, by-product type and by-product use

Commodity use	By-product type	By-product use
Processing involving juicing	Rejected whole fruit	Land application
		Animal feed
	Peel, core and/or stone	Land application
		Animal feed
	Pulp / pomace	Land application
		Animal feed
Processing involving non-juicing	Rejected whole fruit	Land application
		Animal feed
	Peel, core and/or stone	Land application
		Animal feed
Fresh fruit retail	Rejected whole fruit	Land application
	Peel, core and/or stone	Land application

For the three fruit commodities, the distribution of the retailed portion of the commodity between the NUTS2 regions within each country is determined by the human population density, obtained from Eurostat. The proportion of the country total human population located in each NUTS2 region in the country is multiplied by the volume destined for retail in that country to give the volume going to retail in each NUTS2 region. Human population is used as the predictor of the location of end use of raw retailed product.

The distribution of processing of the commodity between NUTS2 regions within each country is determined by an estimate of the numbers of fruit and vegetable processing enterprises in each NUTS2 region. The numbers of fruit and vegetable processors is available at NUTS1 level and the number of general food processors is at NUTS2. The estimate of numbers of fruit and vegetable processors at NUTS2 was obtained by assuming that they were distributed at NUTS2 level in the same geographic pattern as general food processors (Appendix B).

In the case of wheat, losses of the commodity are considered in relation to the sequence from port to mill or "other" and then, for the milling stream, to farm and domestic consumption (Fig. 2.2.03 and Appendix D). Each point of loss has a pathway leading to that loss and the set of pathways is distinguished in the model. Eight waste/loss streams are defined by combinations of location and waste stream (Table 2.2.02).

Losses at the port are recorded and the proportion of wheat imports at each port across the EU is estimated from figures for the tonnage of dry bulk agricultural products. The NUTS2 regions in which these ports are located were identified and the losses at port attributed accordingly.

Industrial losses were attributed to NUTS2 region by the distribution of the commodity used in this way between the NUTS2 regions within each country, determined by the proportion of industrial plants categorized under NACE code 20.14, which includes fermentation of sugarcane, corn or similar to produce alcohol and esters, in each NUTS2 region.

Losses at milling were attributed to NUTS2 region by the distribution of the milling of the commodity between the NUTS2 regions within each country, determined by the proportion of mills in each NUTS2 region. At the mill different product uses are considered and all have some associated losses. Estimates of the percentage of the commodity destined for use in human consumption and animal feed was obtained, as well as estimates of losses at milling.

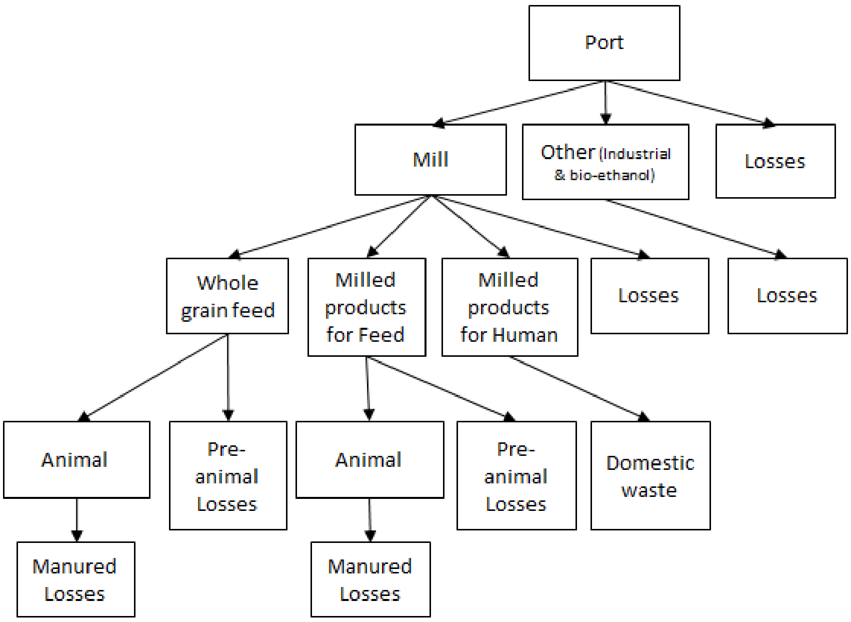


Figure 2.2.03: Structure of the waste streams for wheat

Table 2.2.02: Eight waste/loss streams defined by possible combinations of location and waste stream

Location	Waste steam	Quantity
Port	Port losses	Losses (%)
Mill	Mill losses	Losses (%)
Other (Industrial/Bio-ethanol)	Industrial losses	Losses (%)
On-Farm	Whole grain Pre-animal losses	Losses (%)
	Whole grain Manured losses	% of grain unaffected by alimentary processes
	Milled Product Pre-animal losses	Losses (%)
	Milled Product Manured losses	% of milled product unaffected by alimentary processes
Human Consumer	Domestic waste	% of wheat products to land application

The distribution of livestock-related commodity use between the NUTS2 regions within each country is determined by the proportion of livestock units in each NUTS2 region, obtained from Eurostat. In most cases data were available at NUTS2 resolution but in the cases of Germany and Croatia no information was available so an even distribution within these countries was used. The proportion of the country total livestock units located in each NUTS2 region in the country is multiplied by the volume used in that country to give the volume going to livestock use in each NUTS2 region. The end-use of grains destined for direct livestock use is expected to be well reflected by the location of livestock units.

2.2.6. Vulnerability

Vulnerability concerns the potential for pest transfer if the pest is released from an imported commodity. The vulnerability of a NUTS2 region to transfer by an imported pest depends on two factors. Firstly, the greater the area of the NUTS2 region occupied by vulnerable hosts, the more likely there is an opportunity for pest contact. For each NUTS2 region the area occupied by the vulnerable crop is obtained from the Eurostat crop area database. Wild hosts may need to be added sometimes.

Secondly, the greater the mobility of the pest, the greater is the opportunity for pest contact. A pest 'footprint' was calculated as the area that the pest or pests can potentially reach from a single release point in the period they can survive after release from the imported commodity (or within one month, whichever is the lesser). This area is calculated as the area of the circle with radius equal to the average linear distance that the pest can travel under ideal conditions; the area is expressed as a proportion of the NUTS2 area.

For multiple pest release points the most conservative assumption is taken that the footprints do not overlap; pest escape from the imported commodity is usually a rare event so this may often be reasonable. With two pest release points the area of the footprint therefore doubles, for three it trebles, and so on. In terms of total pest footprint area, the combined area for *n* pest releases, the radius above should be multiplied by $\sqrt{n}$. This represents the worst case, where no overlap in the pest footprints occurs.

Thus we have two quantities: the area of the NUTS2 region occupied by the vulnerable crop and the proportion of the NUTS2 region that can be reached by the pest(s). Whether the two coincide depends on the geography of the vulnerable host and the location of pest release. For a random pest release, then the average area reached by the pest is equal to the product of these two quantities. The maximum is the total pest footprint area or the total area of the vulnerable crop, whichever is the larger. This upper limit occurs for events where the pest release and vulnerable crop entirely coincide geographically. The minimum is zero (in those cases when pest and host do not coincide at all geographically). A measure of vulnerable area (km^2) which takes into account pest mobility is thus obtained. Vulnerability is a measure of potential joint occurrence of released pest and host but does not take into account crop phenology which is incorporated into the calculation later.

2.2.7. Contact

The contact panel (Fig. 2.2.01b/c) brings together the infested volumes associated with the different waste and/or by-product streams of the infested commodity (Tables 2.2.01/02) and the vulnerability of the receptor to determine pest contact potential in each NUTS2 region in each month. The extent of potential contact between commodity and receptor also depends on the viability of the pest having undergone the twelve (or eight for wheat) waste streams described above. Such reduction in viability is taken into account at this point in the calculation.

Any loss of pest viability due to duration and conditions of the waste streams will reduce the infestation level. In the general models this is taken into account by multiplying the infested volume by the reduced viability to give a measure of potential pest challenge expressed as a volume. This is the volume (having taken into account loss of viability) which poses equivalent pest challenge to the same volume at the time of commodity arrival.

In the consignment models, the infested volume and the level of infestation have been kept separate to allow the infested volume and the level of infestation of that volume to be considered in more detail (Section 2.3). In the general models for fruit, twelve potential waste streams with different volumes and pest viabilities are considered at one time so in order to obtain an integrated measure of risk, pest challenge, as a product of volume and infestation level is used. The same applies to the eight loss streams in the general wheat model.

The final step is to incorporate the effect of vulnerable host phenology; not only must contact with a host occur but it must be at the correct stage for the pest concerned to achieve successful establishment. The suitability of the host phenological stage is expressed as the proportion of host production at the correct stage in each MS in each month. The values are grouped according to the geographic zone of commodity production of the Member State but variables for each state are provided separately in case more precise information is available for future cases. Potential contact (100 kg km^2) = Infested volume (100 kg) x vulnerable area (km^2) x susceptible phenology (proportion). The contact is between the pests associated with a volume of infested commodity and an area of vulnerable crop, so the potential for pest contact is proportional to the amount of infested waste/by-product and to the vulnerable area of host with which pests from this waste/by-product can come into contact, e.g. a value of '1' can be interpreted as equivalent to 100 kg infested waste/by-product acting as a potential source of contact with 1 km^2 of crop.

A question arises on how to interpret contact units in which there are very low volumes of infested commodity, for instance where the average level of infestation is less than one fruit. Infested volumes which correspond to less than the weight of a single fruit can be interpreted using the Poisson distribution, a discrete probability distribution that expresses the probability of a given number of events occurring in a fixed interval of time and/or space if these events occur with a known average rate and independently of the time since the last event. The Poisson distribution can also be used for the number of events in other specified intervals such as distance, area or volume.

The values calculated in the model for the volume of infested imports are average values for the weight of infested fruit. In terms of numbers of fruit, these values can be divided by the weight of a fruit to give the average number of fruit. If the value is less than one fruit, the result can be interpreted as the mean of a Poisson distribution of infested fruit number. The distribution shows the probability that no fruit, one fruit, two fruits etc., are infested. If the mean value << 1 fruit then then the probably that no fruit is infested is large and there is some probability that one fruit is infested. The probability that more than one fruit is infested in such circumstances is very low.

An average number of fruit infested which is less than a single fruit therefore has a meaningful interpretation, in terms of a probability distribution of number of fruit infested. Using the Poisson distribution, if the average number of fruit infested is 0.01, then this is approximately equal to a probability of P=0.01 that one fruit is infested. In Fig. 2.2.04 it can be seen that there is 99% chance that zero fruits are infested, a 1% chance (i.e. P=0.01) that 1 fruit is infested and a 0% chance that more than one fruit is infested.

If the average number of fruit infested is 0.02 then it can be seen that there is 98% chance that zero fruits are infested, a 2% chance (i.e. P=0.02) that 1 fruit is infested and a 0% chance that more than one fruit is infested (Fig. 2.2.04).

When an average number of fruit infested of about 0.05 is reached, then it can be seen that there is 95.1% chance that zero fruits are infested, a 4.8% chance (i.e. P=0.048) that 1 fruit is infested and a 0.1% chance that more than one fruit is infested (Fig. 2.2.04).

Above an average figure of about 0.05, therefore, the value of the average number of infested fruit starts to diverge from the value of the probability that one fruit is infested. For low mean values, however, the similarity of the two values provides a useful conceptual interpretation of average fruit numbers (or weights) which are less than one fruit. Of course, as regards exact values, it is an approximation only because it relies on an underlying assumption about independence of events which may not hold in many cases.

As the average increases the probability that more than one fruit is infested also increases. Fig. 2.2.05 shows average values for numbers of fruits infested in the range 0.05 fruits to 1 fruit and the corresponding probability that one *or more* fruits are infested; it can be seen that the two values diverge progressively but are reasonably close below a mean number of infested fruit of about 0.2.

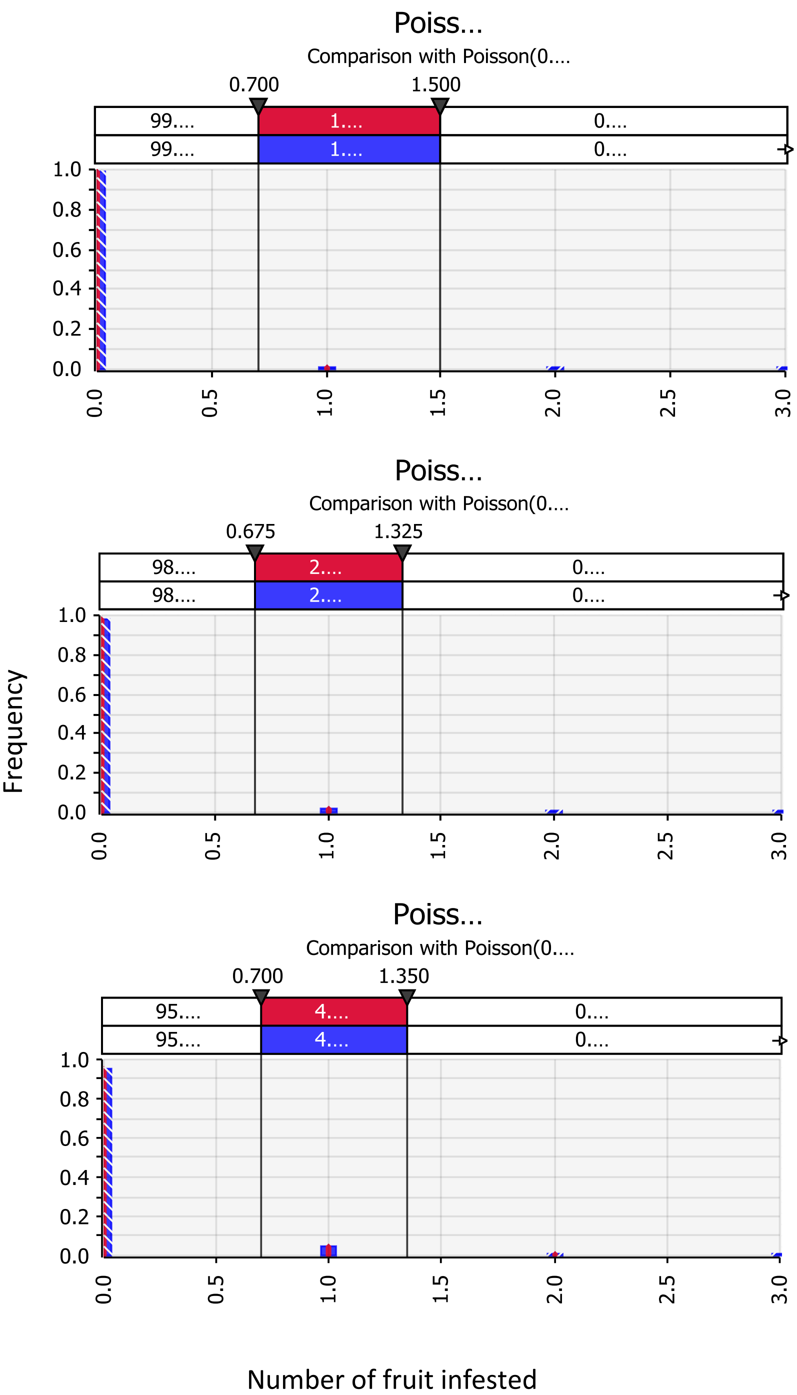


Figure 2.2.04: Example Poisson distributions of number of fruit infested with average values of 0.01, 0.02 and 0.05. The 'cut lines' are position between 0 and 1 fruits and between 1 and 2 fruits to show the probabilities that zero, one and more than one fruit is infested

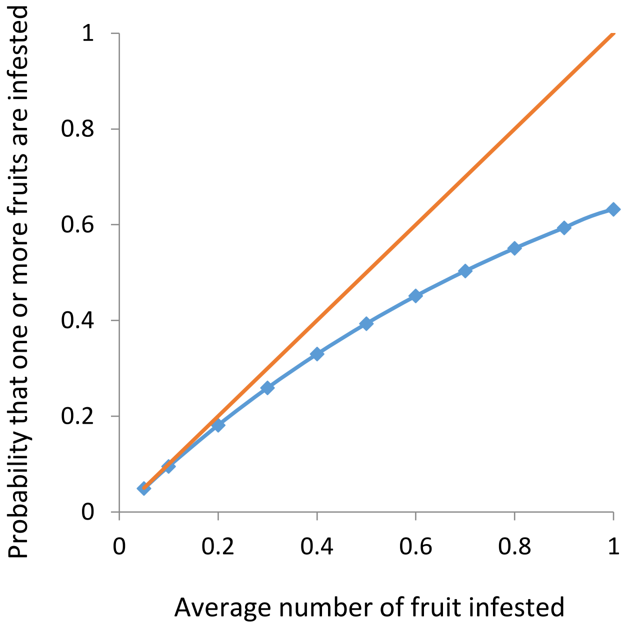


Figure 2.2.05: Relationship between the average number of fruit infested and the probability that one or more fruit are infested. When the average is low, the two values are similar to each other but diverge as the average increases

2.2.8. Summary tables of variables and calculations

The model variables and the calculations are set out for the fruit models and the cereal model in Tables 2.2.03 and 2.2.04, respectively.

Table 2.2.03: List of variables in general models for fruit giving the units, and for calculated variables, the calculation performed. Whether the variable source is data (Eurostat or other) or derived from a calculation, is also indicated. The data sources are detailed in Section 3

Ref	Variable name	Variable units/calculation	Source
Vol	Imports by Source Country by Month	Volume (100 kg), 2011 – 2013. Means for each month or 2013 data only	Eurostat
VolAll	Imports by All Sources by Month	Volume for each month from all source countries (100 kg)	Calc.
Inf%	Infestation levels of Imports by Country by Month	Units of commodity infested (%) ①	Other

Inf	Infested imports by Country by Month	Vol x Inf% (100 kg)	Calc.
InfAll	Infested Imports by all Countries by Month	Means for each month from all source countries (100 kg)	Calc.
CProd	Production of vulnerable commodity by Country by Month	Volume of commodity produced in EU MS (100 kg)	FAOStat
EUExtraExport	Eurostat data on export of commodity to nonEU28	100 Kg	Eurostat
Retainedprop	Proportion of commodity retained prior to EU28 transhipment in each MS by month	1-(EUExtraExport/(VolAll+Cprod))	Calc.
NetInf%	Percentage of all commodity in country infested	InfAll / (VolAll + CProd) (%)	Calc.
Ship	Infested transhipments imported to Country from all other MS by Month	Sum (Vol x NetInf%) (100 kg)	Calc.
Exp	Infested transhipments exported *from* each EU MS by Month	Vol② x NetInf% (100 kg)	Calc.
InfComb	Infested Imports less and net transhipments by all Countries by Month	(InfAll x Retainedprop) - Exp + Ship (100 kg)	Calc.
Proc%	Processing percentage by Country by Month	Volume of commodity processed (%)	Other
ProcN%	Processed in each NUTS2	Proportion in each NUTS2 of country	Other
Juiced%	Processed to juiced processing by country	Proportion by country	Other
JWhole%	Whole fruit rejects from juicing	Proportion by country	Other
JWholeLand%	Juice rejects to land application	Proportion by country	Other
JWholeFeed%	Juice rejects to animal feed	1 - JWholeLand%	Calc.
JPeel%	Peel from juicing	Proportion by country	Other
JPeelLand%	Peel from juicing to land application	Proportion by country	Other
JPeelFeed%	Peel from juicing to feed	1- JPeelLand%	Calc.
JPulp%	Pulp from juicing	Proportion by country	Other
JPulpLand%	Pulp from juicing to land application	Proportion by country	Other
JPulpFeed%	Pulp from juicing to feed	1- JPulpLand%	Calc.
Non-Juiced%	Processed to non-juiced processing by country	1- Juiced%	Calc.

NJWhole%	Whole fruit rejects from non-juiced	Proportion by country	Other
NJWholeLand %	Non-Juiced rejects to land application	Proportion by country	Other
NJWholeFeed %	Non-Juiced rejects to animal feed	1 - NJWholeLand%	Calc.
NJPeel%	Peel from non-juiced	Proportion by country	Other
NJPeelLand%	Peel from non-juiced to land application	Proportion by country	Other
NJPeelFeed%	Peel from non-juiced to feed	1- NJPeelLand%	Calc.
RWhole%	Whole rejects from retailed	Proportion	Other
RPeel%	Peel & core waste from retailed	Proportion	Other
VolJWL	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Reject Whole Fruit; Use: Land Application	InfComb x Proc% x ProcN% x Juiced% x JWhole% x JWholeLand% (100 Kg)	Calc.
VolJWF	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Reject Whole Fruit; Use: Animal Feed	InfComb x Proc% x ProcN% x Juiced% x JWhole% x JWholeFeed% (100 Kg)	Calc.
VolJPL	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Peel and Core; Use: Land Application	InfComb x Proc% x ProcN% x Juiced% x JPeel% x JPeelLand% (100 Kg)	Calc.
VolJPF	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Peel and Core; Use: Animal Feed	InfComb x Proc% x ProcN% x Juiced% x JPeel% x JPeelFeed% (100 Kg)	Calc.
VolJUL	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Pulp; Use: Land Application	InfComb x Proc% x ProcN% x Juiced% x JPulp% x JPulpLand% (100 Kg)	Calc.
VolJUF	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Juicing; Waste Type: Pulp; Use: Animal Feed	InfComb x Proc% x ProcN% x Juiced% x JPulp% x JPulpFeed% (100 Kg)	Calc.
VolNJWL	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Non-Juicing; Waste Type: Reject Whole Fruit; Use: Land Application	InfComb x Proc% x ProcN% x (1-Juiced%) xN JWhole% x NJWholeLand% (100 Kg)	Calc.

VolNJWF	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Non-Juicing; Waste Type: Reject Whole Fruit; Use: Animal Feed	InfComb x Proc% x ProcN% x (1-Juiced%) xN JWhole% x NJWholeFeed% (100 Kg)	Calc.
VolNJPL	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Non-Juicing; Waste Type: Peel and Core; Use: Land Application	InfComb x Proc% x ProcN% x (1-Juiced%) x NJPeel% x NJPeelLand% (100 Kg)	Calc.
VolNJPF	Infested Waste/By-product Volume by NUTS2 by Month - Processing Type: Non-Juicing; Waste Type: Peel and Core; Use: Animal Feed	InfComb x Proc% x ProcN% x (1-Juiced%) x NJPeel% x NJPeelFeed% (100 Kg)	Calc.
Pop%	Annual Population data by NUTS2 by Month	2013 Proportion in each NUTS2 region of country for the period. Numbers 2010 - 2013	Eurostat
VolRW	Infested Waste/By-product Volume by NUTS2 by Month - Retailed; Waste Type: Reject Whole Fruit; Use: Land Application	InfComb x (1-Proc%) x Pop% x RWhole% x RWholeLand% (100 Kg)	Calc.
VolRP	Infested Waste/By-product Volume by NUTS2 by Month - Retailed; Waste Type: Peel and core; Use: Land Application	InfComb x (1-Proc%) x Pop% x RPeel% x RPeelLand% (100 Kg)	Calc.
Host	Commodity Area by NUTS2	Area occupied by vulnerable host (km^2)	Eurostat
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat
Foot%	Pest 'footprint': the proportion of the area that a released pest can reach	Area of footprint calculated from pest mobility range (proportion of NUTS2 region)	Calc.
Vul	NUTS2 area with vulnerable host which is able to be reached by the pest	Host x Foot%④ (km^2)	Calc.
SurJWL%	Pest survival in processing waste	Pest survival (proportion)	Other
SurlJWF%	Pest survival in processing waste	Pest survival (proportion)	Other
SurJPL%	Pest survival in processing waste	Pest survival (proportion)	Other
SurJPF%	Pest survival in processing waste	Pest survival (proportion)	Other
SurJUL%	Pest survival in processing waste	Pest survival (proportion)	Other
SurJUF%	Pest survival in processing waste	Pest survival (proportion)	Other
SurNJWL%	Pest survival in processing waste	Pest survival (proportion)	Other
SurNJWF%	Pest survival in processing waste	Pest survival (proportion)	Other

SurNJPL%	Pest survival in processing waste	Pest survival (proportion)	Other
SurNJPF%	Pest survival in processing waste	Pest survival (proportion)	Other
SurRW%	Survival retail whole waste	Pest survival (proportion)	Other
SurRP%	Survival retail peel & core waste	Pest survival (proportion)	Other
Pinf	Processed imports with viable pest waste stream	VolJWL x SurJWL% + VolJWF x SurlJWF% + VolJPL x SurJPL% + VolJPF x SurJPF% + VolJUL x SurJUL% + VolJUF x SurJUF% + VolNJWL x SurNJWL% + VolNJWF x SurNJWF% + VolNJPL x SurNJPL% + VolNJPF x SurNJPF% (100 kg) ⑤	Calc.
Rinf	Retailed imports with viable pest in waste stream	VolRW x SurRW% + VolRP x SurRP% (100 kg) ⑤	Calc.
Phen%	Host at correct phenological stage to allow transfer of pest from infested import by Country by Month	Proportion of host area at correct stage	Other
Contact	Potential for contact between infested import and hosts by NUTS2 (allocated to one of three EU zones (North, Central and South) by Month	(Pinf + Rinf) x Vul x Phen% (100 kg km^2)⑥	Calc.

①e.g. proportion of fruits; ②In this case, the total exported by each MS to other MSs;③Liv% replaces Pop% in the case of wheat; ④on average, the pest can reach that proportion of the host area determined by its mobility (defined by 'footprint' size);⑤100 kg at an infestation level equivalent to that at imports after taking into account pest mortality; ⑥the potential for pest contact is proportional to the amount of infested waste/by-product and to the vulnerable area of host with which pests from this waste/by-product can come into contact, e.g. a value of '1' can be interpreted as equivalent to 100 kg infested waste/by-product acting as a potential source of contact with 1 km^2 of crop.

Table 2.2.04: List of variables in general models for wheat giving the units, and for calculated variables, the calculation performed. Whether the variable source is data (Eurostat or other) or derived from a calculation is also indicated. The data sources are detailed in Section 3

Ref	Variable name	Variable units/calculation	Source
Vol	Imports by Source Country by Month	Volume (100 kg) 2011 – 2013. Means for each month or 2013 data only	Eurostat
VolAll	Imports by All Sources by Month	Means for each month from all source countries (100 kg)	Calc.
Inf%	Infestation levels of Imports by Country by Month	Units of commodity infested (%) ①	Other
Inf	Infested imports by Country by Month	Vol x Inf% (100 kg)	Calc.
InfAll	Infested Imports by all Countries by Month	Volume each month from all source countries (100 kg)	Calc.
CProd	Production of vulnerable commodity by Country by Month	Volume of commodity produced in EU MS (100 kg)	FAOStat
EUExtraExport	Eurostat data on export of commodity to nonEU28	100 Kg	Eurostat
Retainedprop	Proportion of commodity retained prior to EU28 transhipment in each MS by month	1-(EUExtraExport/(VolAll+Cprod))	Calc.
NetInf%	Percentage of all commodity in country infested	InfAll / (VolAll + CProd) (%)	Calc.
Ship	Infested transhipments imported to Country from all other MS by Month	Sum (Vol x NetInf%) (100 kg)	Calc.
Exp	Infested transhipments exported *from* each EU MS by Month	Vol② x NetInf% (100 kg)	Calc.
InfComb	Infested Imports and net transhipments by all Countries by Month	(InfAll x Retainedprop) - Exp + Ship (100 kg)	Calc.
Port%	Potentially –infested Imports by NUTS 2 location of the Port of entry	Proportion of EU imports entering in each NUTS2	Other
PortLoss%	Grain losses at port	Proportion	Other
Ploss	Infested losses at Port by NUTS2 by Month	InfAll x Port% x PortLoss% (100 kg)	Calc.
ToMill%	Percentage of grain going to mills (rather than industrial uses) by Country by Month	Volume of commodity milled (%) (as opposed to use as whole grain	Other
MillN%	Milling in each NUTS2	Proportion in each NUTS2 of country	Other

MillLoss%	Grain losses during milling/en-route to milling	Proportion	Other
Mloss	Infested losses at Mill by NUTS 2 by Month	InfComb x ToMill% x MillN% x MillLoss% (100 kg)	Calc.
ToInd%	Percentage going to industrial uses	Proportion	Other
IndN%	Industrial / bioethanol use by NUTS2	Proportion in each NUTS2 of country	Other
IndLoss	Infested losses at Industrial by NUT2 by Month	InfComb x ToInd% x IndN% x IndLoss% (100 kg)	Calc.
Pop%	Annual Population data by NUTS2 by Month	2013 Proportion in each NUTS2 region of country for the period. Numbers 2010 - 2013	Eurostat
ToCons%	Percentage going to human consumption	Proportion	Other
ConLoss%	Losses from grain product human consumption	Proportion	Other
HuLoss	Infested losses at human consumers by NUT2 by Month	InfComb x Pop% xToCon% x ConLoss% (100 kg)	
Liv%	Annual Livestock Units by NUT2 region by Month	Proportion in each NUTS2 region of country for the period. Numbers 2011 - 2013	Eurostat
ToFarm%	Infested volume on Farm by NUTS 2 by Month	Proportion	Other
LossGPre%	Percentage going to farm which is lost as whole grain prior to consumption	Proportion	Other
LossGUn%	Percentage going to farm which is lost as whole grain unaffected by alimentary processes (Undigested)	Proportion	Other
LossFPre%	Percentage going to farm which is lost as feed prior to consumption	Proportion	Other
LossFUn%	Percentage going to farm which is lost as feed unaffected by alimentary processes (Undigested)	Proportion	Other
VolGPre	Whole grain prior to consumption loss volume by NUTS2 by Month at farm	InfComb x Liv% x ToFarm% x LossGPre% (100 kg)	Calc.
VolGUn	Whole grain unaffected by alimentary processes loss volume by NUTS2 by Month at farm	InfComb x Liv% x ToFarm% x LossGUn% (100 kg)	Calc.
VolFPre	Feed prior to consumption loss volume by NUTS2 by Month at farm	InfComb x Liv% x ToFarm% x LossFPre% (100 kg)	Calc.
VolFUn	Feed unaffected by alimentary processes loss volume by NUTS2 by	InfComb x Liv% x ToFarm% x	Calc.

	Month at farm	LossFUn% (100 kg)	
Host	Commodity Area by NUTS2	Area occupied by vulnerable host (km^2)	Eurostat
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat
Foot%	Pest 'footprint': the proportion of the area that a released pest can reach	Area of footprint calculated from pest mobility range (proportion of NUTS2 region)	Calc.
Vul	NUTS2 area with vulnerable host which is able to be reached by the pest	Host x Foot%④ (km^2)	Calc.
SurPL%	Pest survival in grain lost at port	proportion	Other
SurIn%	Pest survival in grain lost at/en-route to industrial uses	proportion	Other
SurML%	Pest survival in grain lost at Mill/en-route to mill	proportion	Other
SurGP%	Pest survival in grain lost at farm prior to feeding	proportion	Other
SurGU%	Pest survival in grain undigested by livestock	proportion	Other
SurFP%	Pest survival in feed lost at farm prior to feeding	proportion	Other
SurFU%	Pest survival in feed undigested by livestock	proportion	Other
SurHu%	Pest survival in grain products lost at or en route to consumer	propoortion	Other
InfPL	Port losses with viable pest	PLoss x SurvPL% (100 kg) ⑤	Calc.
InfInL	Industrial Losses with viable pest	IndLoss x SurIn% (100 kg) ⑤	Calc
InfML	Mill losses with viable pest waste stream	MLoss x SurML% (100 kg) ⑤	Calc.
InfGP	Whole grain pre-consumptions farm losses with viable pest in waste stream	VolGPre x SurGP% (100 kg) ⑤	Calc.
InfGU	Feed pre-consumption farm losses with viable pest in waste stream	VolGUn x SurGU% (100 kg) ⑤	Calc.
InfFP	Grain undigested by livestock farm losses with viable pest in waste stream	VolFPre x SurFP% (100 kg) ⑤	Calc.
InfFU	Feed undigested by livestock farm losses with viable pest in waste stream	VolFUn x SurFU% (100 kg) ⑤	Calc.
InfCL	Human consumption losses with viable pest	HuLoss x SurHu% (100 kg)	Calc.

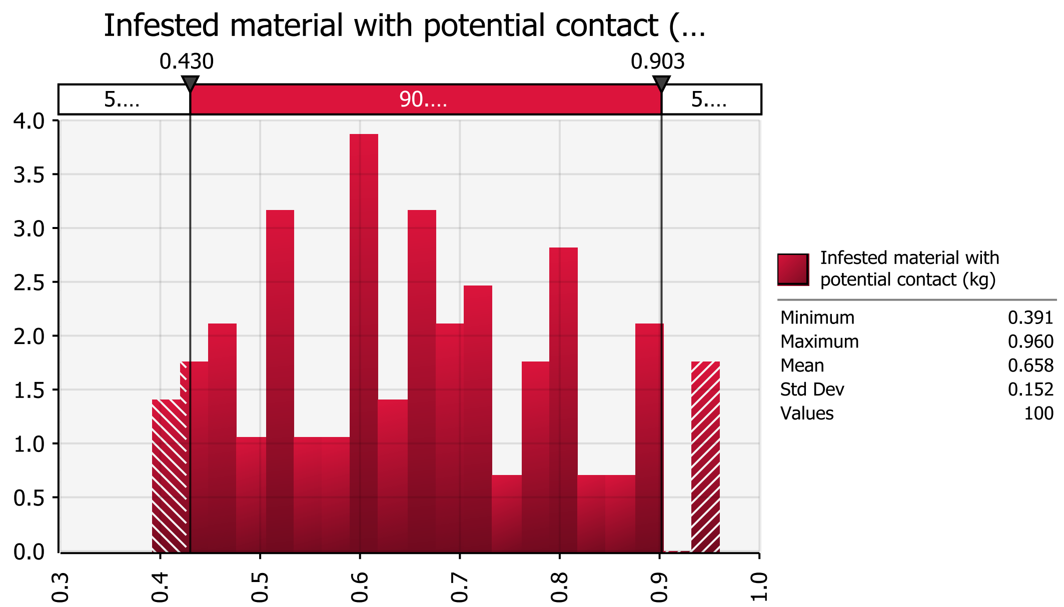
Phen%	Host at correct phenological stage to allow transfer of pest from infested import by Country by Month	Proportion of host production at correct stage	Other
Contact	Potential for contact between infested import and hosts by NUTS2 (allocated to one of three EU zones (North, Central and South) by Month	(InfPL + InfInL + InfML + InfGP + InfGU + InfFP + InfFU + InfCL) x Vul x Phen% (100 kg km^2)⑥	Calc.

①e.g. proportion of grains; ②In this case, the total exported by each MS to other MSs;③Pop% replaces Liv% in the case of fruit; ④on average, the pest can reach that proportion of the host area determined by its mobility (defined by 'footprint' size);⑤100 kg at an infestation level equivalent to that at imports after taking into account pest mortality; ⑥the potential for pest contact is proportional to the amount of infested losses and to the vulnerable area of host with which pest from this loss can come into contact, e.g. a value of '1' can be interpreted as equivalent to 100 kg infested losses acting as a potential source of contact with 1 km^2 of crop.

2.2.9. Output table and graphics

The final panel in the main page of Module 2 is labelled 'Output table and graphics'. This part of the model brings together some key outputs. 'Contact potential' is given by month and by NUTS2 and for ease of comparability, using a single value, this integrates the volume of infested material with potential contact (100 kg) and the vulnerable area accessible by pest (km^2) as a single figure, the product of these two. Though useful as a comparable measure of risk, it may be easier to interpret by keeping the amount of infested material and the size of the vulnerable area separate. In the sheet labelled 'Summary Output: Infested material to vulnerable crop by NUTS2 per year' two columns of values are provided: 'Infested material with potential contact' (summed over the year) and the 'average vulnerable area accessible by pest' (averaged over the year). Because the magnitude of the values can vary very widely, a choice of units is provided using dropdown menus, (g, kg, or 100 kg) and (m^2, ha, km^2), respectively. These two sets of values summarise the two dimensions of the two parts of transfer risk: the amount of infested material that can lead to pest contact and the vulnerable crop area that a pest associated with this infested material could be expected to reach. As with the rest of the model, any cell can be designated a 'risk output' so that the underlying distribution of values can be seen. In this table the country totals have been pre-designated as risk outputs and the distributions of infested volume and vulnerable area are shown in Fig. 2.2.06 (example for Belgium).

These two dimensions are plotted in a series of graphs, of country totals (linear and log Y axis) of NUTS2 regions of in country separately. The example for Belgium is illustrated (Fig. 2.2.07). The positions of the different NUTS2 regions can be interpreted as follows, for example BE31 Brabant Wallon has a high vulnerable area (in the context of Belgium) but a low amount of infested material entering, whereas BE25 Antwerpen has a relatively low vulnerable area but a relatively high amount of inoculum entering. In general, higher risk is associated with a high value on both axes (the top right hand side of the graph area). The units selected in this case were kg and ha.



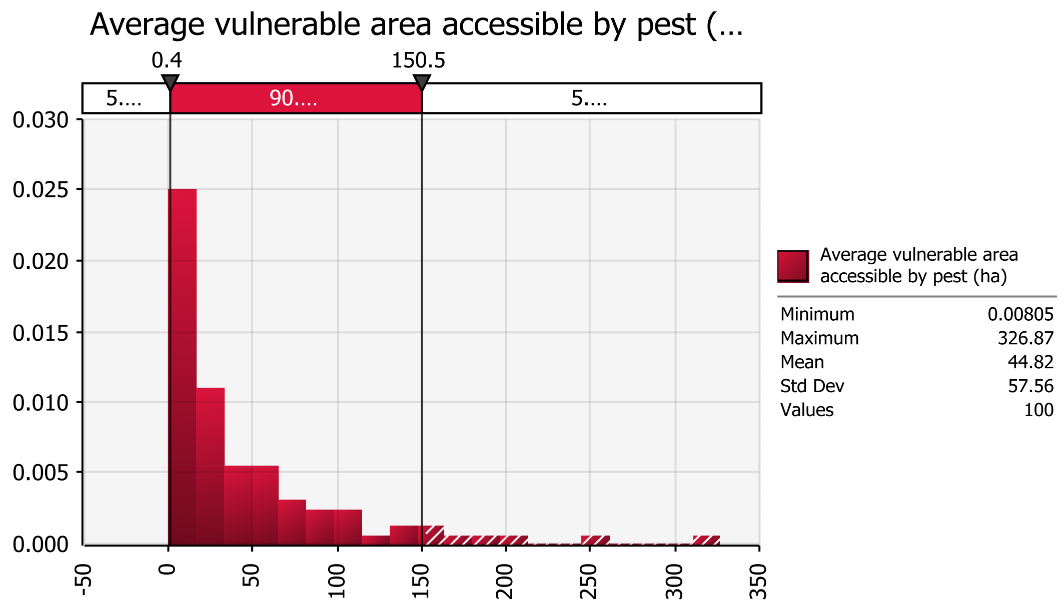


Figure 2.2.06: Distributions of total infested volume of apple waste and average total vulnerable area of apple production in Belgium

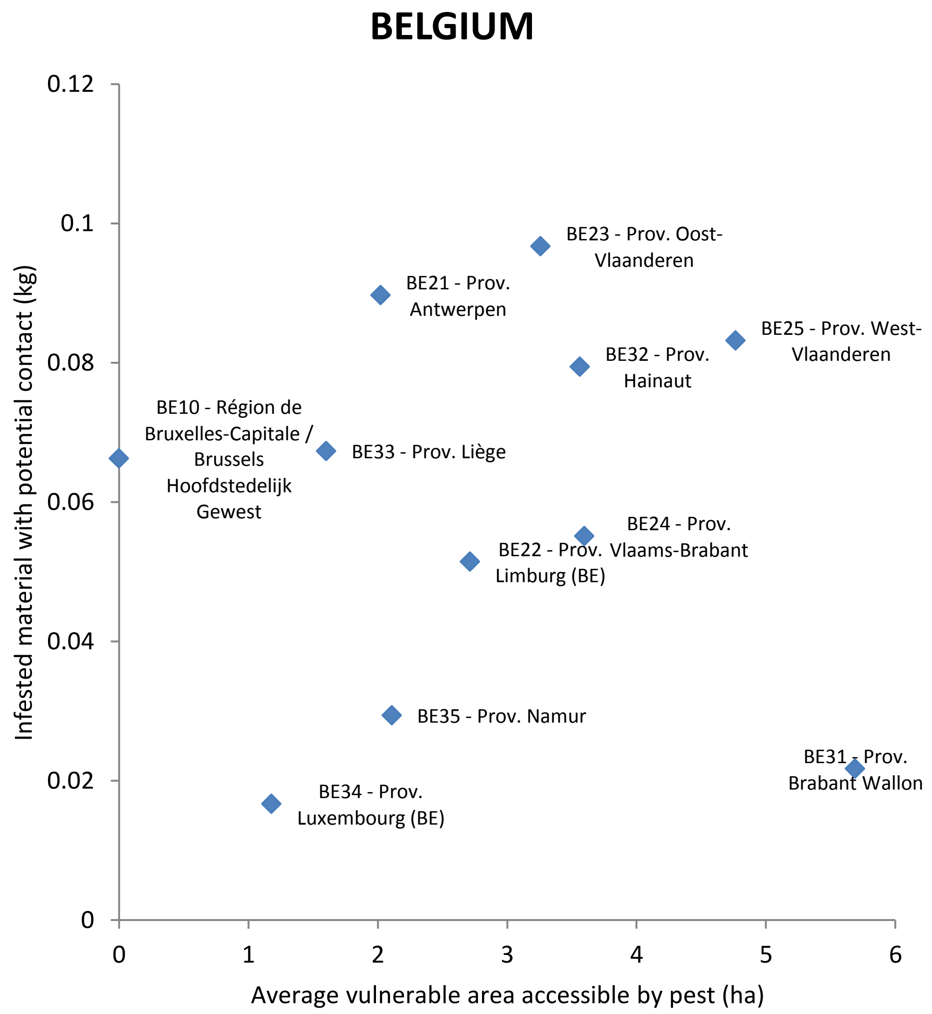


Figure 2.2.07: Model output graphic for Belgium (see text for details)

2.3. Consignment models

2.3.1. User overview

Software requirements

The model requires Microsoft Excel 2007 or 2010 and Palisade @Risk v6 add-in for Excel software.

Generality of the model structure

The structure of Apple single consignment model is identical to that of the other fruit commodity single consignment models, so that when a user is familiar with one model the use of the others is straightforward. The structure of the wheat model follows a similar structure but is modified to reflect the differences in pathways, uses and losses; nevertheless when one is familiar with the fruit single consignment model then using the wheat model will also be relatively straightforward and vice versa.

Model flow and annotation

The "Main" worksheet of the model provides a flow chart of the model structure. In the "Parameter" sheet user input cells / sheets are highlighted in pale blue, all other cells are locked to prevent accidental editing of the model structure. The model has been designed to be as self-explanatory as possible and, to this end, every worksheet in the model contains text box descriptions and comments of the data/workings of that particular sheet and how it relates to other sections.

2.3.2. Model structure

In the single-consignment models the Europe-wide trade routes provided in the general models are tracked in time for specific trade chains that might be taken by a consignment of a fruit or grain commodity. The models are parameterized on real time scales (from the point of arrival in an EU Member State) to reflect the time taken in geographical distribution and fate of the commodity after arrival. The models track the distribution of commodity volume and of its waste, pest losses in the commodity and its waste due to transport storage and use/processing, and the time scale over which these events take place.

The trade network for consignments of fruits entering the EU is shown in Fig. 2.3.01. From the point of entry at an airport or a harbour, the consignment may be transported direct to retailer, wholesaler or to the processing industry. The wholesale facility may include auction, packaging or storage. This acts as an intermediary for onward transport to retailers or processors. Both fresh and processed products are transported to retailers and then by consumers for end use.

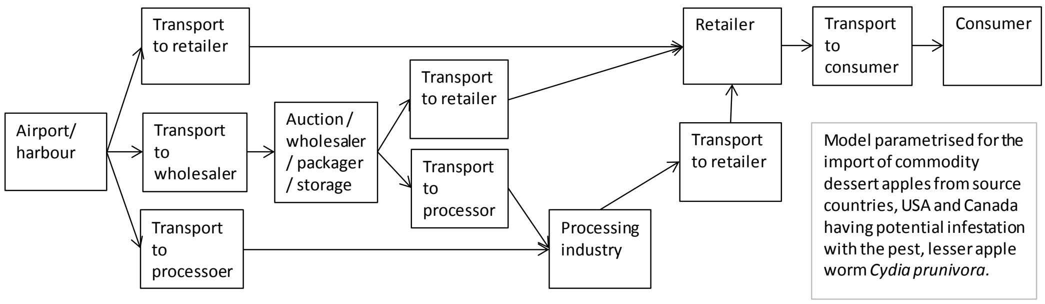


Figure 2.3.01: The trade network for fruits – a consignment may take any route through this network

The single consignment model is required to consider the fate of infested commodity along a single trade chain and the network (Fig. 2.3.01) can be considered as four such possible trade chains or routes through the network (Fig 2.3.02). The structure of the model provides for flexibility within a trade chain. For example if storage took place at retail premises prior to sale, the transport time from storage to retail would be zero, but the two functions of the single premises would still be accounted for separately because the extent of waste or by-product and the implications for pest survival associated with storage and retail may differ.

The simplest model is of Trade chain 1 (Fig. 2.3.02) where the commodity passes from port to retailer to customer. In Trade chain 2 the consignment goes to the retailer via a wholesaler/packer/storage. Trade chains 3 and 4 concern the processing industry; in Trade chain 3 it goes to the processor via a wholesaler/packer/storage; and in Trade chain 4 it goes direct from port to processor. Following processing a very small proportion of commodity, if any, is expected still to contain viable pests but these chains are followed to the final consumer to account for fresh fruit processed in ways which may permit pest survival, e.g. chopped fresh fruit.

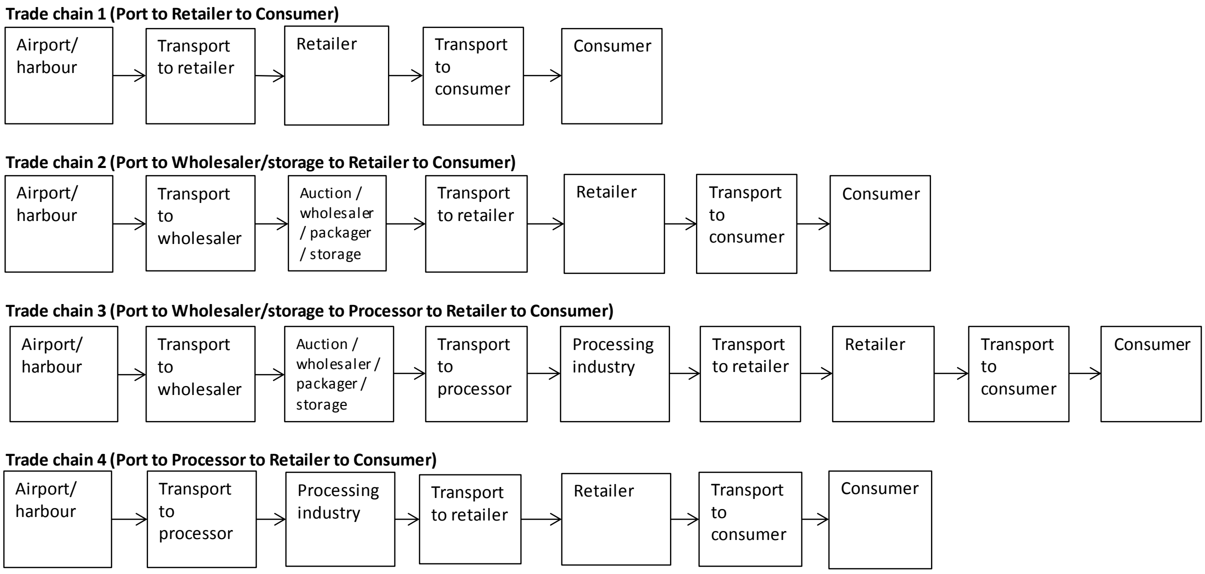


Figure. 2.3.02: The four routes for fruit defined by the network in Fig. 2.3.01

2.3.3. Model inputs

Those cells requiring data inputs (in the form of variable distributions) are indicated with pale blue shading (Fig. 2.3.03). Data input is managed in a single parameter entry sheet which feeds the values which define the input distributions to all the trade chain model sheets, as appropriate. The parameter entry template, data sources and the selection of parameter values for model variables are described in Section 3.2.

Each trade chain occupies a separate sheet. The layout on these sheets (Fig. 2.3.03) is divided into three sections: the upper section defines the distribution of time (days) of the commodity and its waste, the middle section defines the distribution of commodity volume (kgs) and the lower section defines the level of infestation of the commodity with the pest (relative to the infestation on arrival). The commodity itself and the loss, waste or by-product associated with each stage have different parameters associated with them to reflect differences in fate of the commodity and of its losses, waste or by-product.

Overlaid on the time distributions is a diagram depicting the sequence of the calculations. Here, there are two sets of inputs: a set of distributions which define the duration of each stage of the pathway in days to the point where the commodity moves to the next stage, and a set of distributions which define the duration of each stage of the pathway in days to the point where the commodity is lost, wasted or assigned to by-product.

To define the infested commodity volumes, this part of the model starts with the consignment volume on arrival at the airport or harbour (100kgs) and the proportion of consignment units infested. Subsequently a set of inputs then define the proportion of commodity volume passed from one stage to the next; the remainder becoming lost, waste or by-product in that stage.

Pest infestation level is calculated separately from infested volume because pest mortality along the trade chain may cause a reduction the level of infestation of a unit of commodity but not necessarily the number of infested units of commodity. For this reason the two quantities are provided separately. Two sets of inputs are used to define pest mortality: one concerning the daily pest mortality rate in the commodity itself and that in the proportion of the commodity that is lost, wasted or becomes a by-product.

2.3.4. Calculation of outputs

Each trade chain model sheet has a results summary box which is automatically updated whenever sheet values change. For each stage in the trade chain the summary box provides a sentence of the following form: "The infested losses, waste or by-product at *stage w* are *x* kg with *y*% of arriving pests surviving after a mean of *z* days", where *w* is the name of every stage including transport and *x*, *y* and *z* are mean values linked to appropriate cells of the model. If there are no losses at a point in the chain then "none at this stage" is displayed.

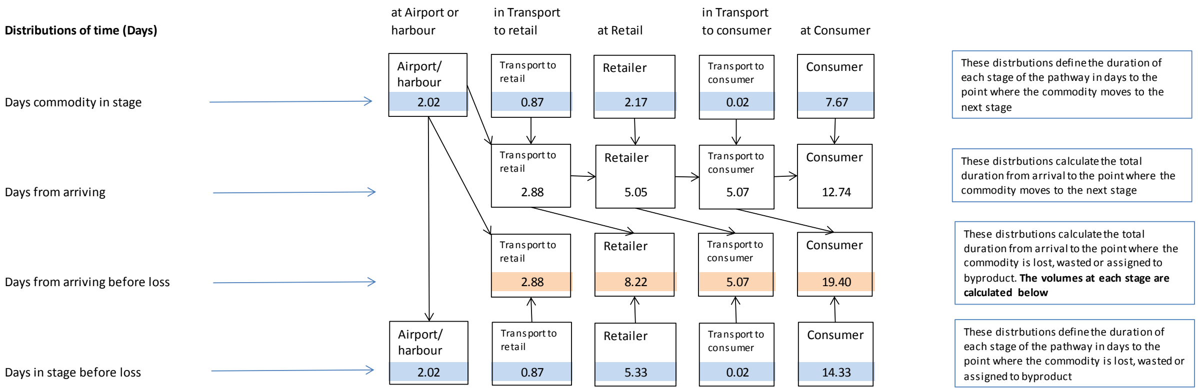
For the time distributions, there are two calculations: one giving the total duration from arrival to the point where the commodity moves to the next stage; the other the total duration from arrival to the point where the commodity is lost, wasted or assigned to by product in a stage. The cumulative times to reach loss, waste or by-product are most important for our purposes so these cells are highlighted in pale orange.

Trade chain 1 (Port to Retail to Consumer)

Results summary

Infested losses, waste or by-product:

at Airport or harbour are 0.0003kg with 85% of arriving pests surviving after a mean of 2 days
in Transport to retail are none at this stage
at Retail are 0.0009kg with 53% of arriving pests surviving after a mean of 8.2 days
in Transport to consumer are none at this stage
at Consumer are 0.0102kg with 39% of arriving pests surviving after a mean of 19.4 days



	on arrival	at Airport or harbour	in Transport to retail	at Retail	in Transport to consumer	at Consumer
Volume of commodity						
Consignment volume 100s kgs	51.83333333					
Proportion of consignment units infested	5.66667E-06					
Proportion commodity retained during stage		0.990	1.000	0.970	1.000	0.640
Cumulative proportion in commodity		0.990	0.990	0.960	0.960	0.615
Infested volume in commodity (kgs)		0.029	0.029	0.028	0.028	0.018
Volume of loss, waste or by product						
Proportion in waste/loss/byproduct		0.010	0.000	0.030	0.000	0.360
Cumulative proportion waste/loss/byproduct		0.010	0.000	0.030	0.000	0.346
Infested volume in waste (kgs)		0.000	0.000	0.001	0.000	0.010
Time-dependent infestation level						
Daily pest mortality rate in commodity		0.075	0.075	0.075	0.038	0.038
Daily pest mortality rate in waste etc		0.075	0.075	0.075	0.038	0.038
Pest survival in commodity stage		0.854	0.934	0.844	0.999	0.745
Cumulative pest survival in commodity stage		0.854	0.798	0.673	0.673	0.501
Pest survival in waste from commodity stage		0.854	0.934	0.659	0.999	0.577
Infestation (proportion of that on arrival) in waste		0.854	0.798	0.525	0.673	0.388

These values define the proportion of commodity volume passed from one stage to the next

These values calculate the volume of commodity remaining at each stage

These values calculate the volume of commodity lost, wasted or assigned to byproduct at each stage

These values calculate the infestation level of the commodity lost, wasted or assigned to byproduct at each stage (as a proportion of the infestation on arrival)

Figure 2.3.03: Model sheet for the trade chain from port to retailer to consumer. This is Trade Chain 1 in all the fruit models; values for apple are shown. The blue-shaded cells indicate variable inputs; the orange-shaded cells indicate outputs of particular interest which are also summarized by the automatically-updated text in the box at the top of the sheet. All values shown are means; graphs showing the distribution of values of inputs and outputs are accessed 'under' the respective cells using the @Risk add-on in the usual way. A similar model layout is used for the other three trade chains

For the volume distributions, a calculation is made of the volume of commodity remaining at each stage and from this of the volume of commodity lost, wasted or assigned to by-product at each stage. The latter are highlighted in pale orange and are the volumes corresponding to the time distributions above.

For the pest survival distributions, a calculation is made of the infestation level of the commodity that is lost, wasted or assigned to by-product at each stage. This is based on the pest mortality rates under the conditions and durations of the various stages and is expressed as a proportion of the infestation on arrival. These values are also highlighted in pale orange and give the infestation levels corresponding to the infested volumes and time distributions above.

The three fruit commodity models have the same structure but differ in the importance of particular trade chains and in the nature and extent of losses, waste or by-product associated with each stage.

Model parameters reflect these differences and are discussed in Sections 3.1 and 3.3. The wheat commodity model has a different structure from the fruit models (Fig. 2.3.04 and Fig. 2.3.05); the calculations relating the succession of stages to each other is the same as described for the fruit models.

The Consignment model is independent of country. The commercial market for fresh produce in Europe is a highly integrated international business that uses standardised technology and processes to achieve rapid high volume throughput to meet uniform customer expectations across the continent (Hingley et al. (2005). Standards are set by international wholesalers, large supermarkets and groups representing supply chain businesses (Ethical Corporation, 2006; Fernandez-Stasrk et al., 2011). The main differences between national markets are expected to be in the proportions entering different marketing paths, such as fresh or processed. Imported fruits in the EU are expected to meet market standards that include being "practically free from pests", hence all estimated infestation ranges are very low.[2] The structure of the Consignment model includes a choice of route that is relevant to the individual consignment, and while the likelihood a particular route being relevant to an individual consignment in different countries may differ, the actual commercial process within that path is expected to be uniform throughout Europe, and increasingly so in the future.[3] The Consignment model does not extend to transfer to local hosts, which would differ considerably from country to country.

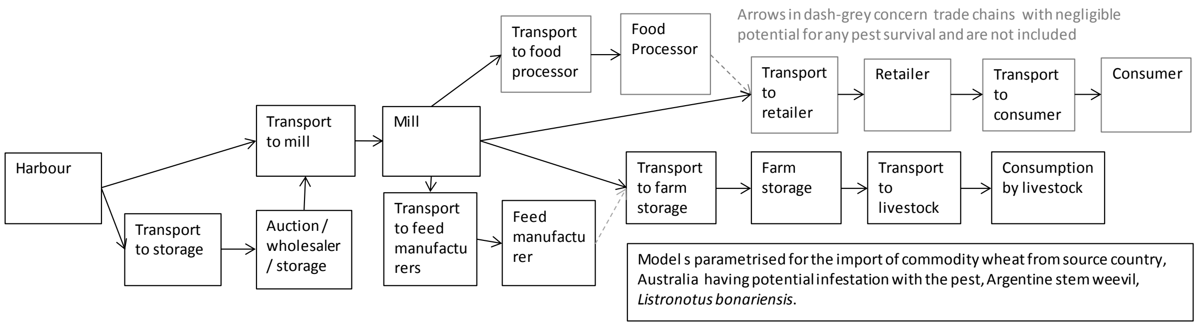


Figure 2.3.04: The trade network for wheat – a consignment may take any route through this network

[2] http://www.freshquality.eu/php/document.php?catdoc_id=49
[3] http://www.cbi.eu/sites/default/files/study/channels-segments-europe-fresh-fruit-vegetables-2014.pdf

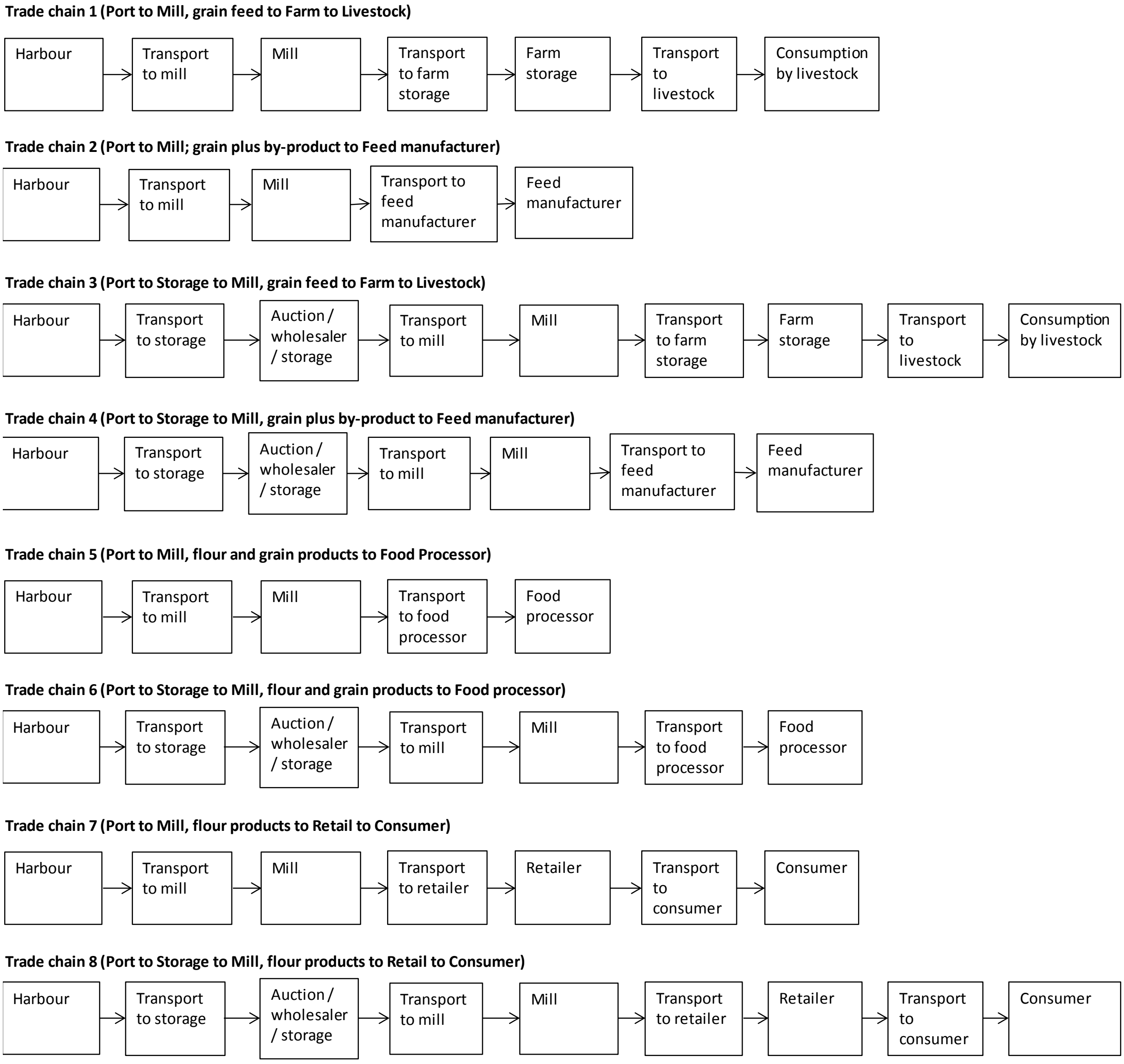


Figure 2.3.05: The eight routes for wheat consignments, defined by the network in Fig. 2.3.04

3. Data Sourcing and Parameter Value Estimation

3.1. General data sourcing

3.1.1. Data sources, selection and extraction of plant product-specific parameter values

Introduction

The project contract defined the case study commodities as shown in Table 3.1.01 as the example pathways to be studied.

Table 3.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities

Commodity category	Example product	Product imported from case study countries
Pome fruit	Fresh apples	Canada, USA
Stone fruit	Fresh plums	Canada, USA
Citrus	Fresh sweet oranges	Any country where *X. citri citri* occurs (many countries).
Cereals	Wheat	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

To inform parameterization of the pathway models for each commodity, several types of information were collected. The information was used to provide the rationale for selecting the estimated values for several of the quantitative inputs required in the @Risk Excel models describing the likelihood of pest entry via selected case study pathways on one of four commodity types (Table 3.1.01). The aim of this report is to describe and discuss the data sources used with respect to the plant product commodities. Detailed descriptions of the sources used are in each of the pathway reports in Appendices 1-4. This report provides an overview of data gathering with some discussion. Further guidance on other data sources is given in Appendices 5 and 6.

Approach to data gathering

When searching for, and then using, data generated by other scientific studies, the method known as "systematic literature review" (SLR) is regarded as providing the highest level of evidence (level 1), whereas using descriptive studies and drawing on expert opinions represents level 7 (Higgins & Green, 2009). Using SLR is most appropriate when a large body of research work exists on a specific study question. SLR allows researchers to focus in on relevant studies from a pool of a larger body of work enabling the reviewers to address a very specific question. SLRs enable researchers to focus in on relevant material in an unbiased way, and the systematic approach to analysis adds credibility to research findings. Typically a conventional Cochrane-type systematic review would normally be expected to take 12 months (Higgins & Green, 2009). SLRs provide a rigorous and replicable method to identify, evaluate and summarise scientific evidence. The method originates in medicine in relation to disease treatments, disease prevention and diagnosis and was developed as a result of the need to identify, evaluate and summarise unmanageable quantities of public health research to aid decision makers.

The use of SLR for plant health purposes was used in the EFSA funded project *Prima phacie* (MacLeod *et al*., 2012). However, the approach revealed that very often there is not a large body of literature on the plant health topics that were being investigated.

Given that the current project had to find many different types of information to inform values for model parameter estimates for four different commodity types (Table 3.1.01) and four case study pests, for many steps along each pathway, there was no single narrow question that could be the subject of a SLR. Instead very many separate questions were required about the plants and plant products. For example, concerning where they are grown; how they are cultivated; how pests are managed on them; how the crops are harvested and transported; processing procedures and waste management. Thus it was not appropriate to use SLRs to collect data in this project. Instead, conventional literature searching techniques and subsequent "hand searching" (a tool also used in SLR) was used.

Plant product data sources

Four working papers, one for each case study commodity and the case study pest selected for that commodity describe in detail the pathways and data sources from which model parameter values are derived. The four working papers are:

- Appendix A. Citrus (sweet oranges) with potential infestation by *Xanthomonas citri citri*
- Appendix B. Pome fruit (apples) from USA and Canada with potential infestation by *Cydia prunivora*
- Appendix C. Stone fruit (plums) from USA or Canada with potential infestation by *Conotrachelus nenuphar*
- Appendix D. Wheat from South America and Oceania with potential infestation by *Listronotus bonariensis*

Each detailed working paper describes the data sources and literature from which information was collected. Very often the precise information or data values that were being sought as model input variables were not available and so some interpretation was necessary to convert what was available into appropriate model parameters for either a "general commodity model" or for a specific "consignment model" parameter. Sections 3.2 and 3.3 show how each model parameter was derived from the relevant commodity-pathway working paper.

This report outlines the searching technique and data sources used with respect to the plant product commodities.

Commodity Production

To understand a potential pathway, some background knowledge of the commodity is required. A good starting point is to find out about production at pathway origin. Some Information on the production of each case study commodity is generally collected for official purposes and is available via websites such as FAOStat (http://faostat3.fao.org/browse/Q/QC/E). Time series data (area (ha), production (kg, tonnes)) can be downloaded in Excel. Some crop data is not reported individually, e.g. statistics describing plum production can often be merged with production of sloes. Quite often data for most recent years is not yet available. Individual Third Countries also produce official statistics that can be available via websites, e.g. NASS (2015).

For large countries like USA and Canada, official (government) studies report production at a state level. Search terms such as "Canadian production statistics for plums" in Google reveal a number of websites that describes the production volume of plums and their markets e.g. % of plums for fresh market, % for export, % for processing. Some Third Countries also produce information sheets about various agricultural and horticultural sectors for marketing purposes. For example in the USA, the Agricultural Marketing Resource Centre provides information sheets on 23 different fruits, including apples (http://www.agmrc.org/commodities__products/fruits/apples/commodity-apple-profile/). Such websites provide information to allow a basic understanding of the industry.

Maps showing the global distribution of the area harvested (hectares per km - harea) and yield (tonnes per km - prod) for 175 crops have been made available by EPPO via their CAPRA website (http://capra.eppo.org/maps.php.). The data used to generate the maps were downloaded from a McGill University website (http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html) and a full description is provided by Monfreda *et al.* (2008). The maps on the EPPO website represent the top 5% of the world crops distribution (i.e. the 95% quantile). The EPPO maps are of use for many plant health and pest risk studies.

Growing practices and harvesting

The respected international organization CABI provides information sheets for specific crops within their Crop Protection Compendium, available online via subscription. For example, the datasheet for apple (*Malus domestica*) (CABI CPC, 2013) describes agronomic aspects (i.e. cultivation and pest management practices) as well as other useful information and additional references.

A description of harvesting is provided for each commodity in each working paper report. Such descriptions were sourced from industry sector websites and reference books (as opposed to research papers) (details are provided in the commodity-pathway reports).

International trade statistics

Goods that are imported (and exported) have to be declared for customs duty purposes. Goods, including imported fruit, are declared using a numerical coding system. The World Customs Organization operates a global coding system referred to as the Harmonized System (HS). Within Europe the EU follows the HS system but also includes further subdivisions, hence the system within the EU has a different name and is referred to as Combined Nomenclature (CN). CN codes comprise of up to eight digits and a text description. Each case study plant product working paper lists the CN codes in which they could be classified. Apart from a few major products, international trade classifications do not provide a detailed classification of processed products according to the primary commodity used in its preparation.

Eurostat provides monthly and annual import data for goods with a CN code from Third Countries into any EU Member State. Volumes and values of goods can be accessed. Data can be downloaded in various formats, including Excel from Eurostat. Three years monthly import data for each commodity is already held in the data-frames, built into the Excel pathway models, of each plant product commodity. Other earlier years, or projected trade scenario values could also be used as alternatives.

Transport

Information regarding methods of transport and conditions in which plant products and other commodities are shipped are available via cargo handlers websites e.g. Anon (2006), GDV (2014). The typical seasonality of varieties of fresh produce is available via FPJ (2010). Actual monthly import data has been collected from Eurostat and is stored in the data-frames.

Import regulations and marketing

The Plant Health Directive specifies the requirements that must be met for regulated articles (plants and plant products requiring a phytosanitary certificate before entry into the EU) whilst marketing standards are described by Freshfel Europe (2011).

Distribution of fresh plant products within the EU

Imported fruit (apples, plums, oranges) that are largely consumed as fresh fruit are assumed to be distributed in proportion to human population density within the EU MS that imports that commodity, or within EU MS into which the commodities are transhipped. Human population density at NUTS2 spatial scale is available via Eurostat and has been downloaded into data-frames for use in the Excel models.

Regarding wheat, the fourth commodity pathway studied, imported wheat is dispersed in accordance to the distribution of flour mills in EU MS. The larger flour mills are most likely to be situated close to ports of entry through which they receive imported wheat, whilst most of the smaller mills are likely to be distributed in line with population density. Attempts to establish the number of mills by NUTS2 regions is problematic because information on the number of mills is dispersed, often out of date, with no indication of size. Thus, a relatively large number of flour mills in one NUTS2 region may have a total capacity which is lower than that of a single, or a few, large flour mills in another NUTS2 region. The most reliable information is obtainable from government statistical departments and trade bodies (e.g. The European Flour Millers Association, www.flourmillers.eu). However, where the former often publish the total number of mills they do not always distinguish by size, whilst the latter will often only include the larger processing operators among their members. An additional source of information is from trade directories (e.g. https://companylist.org and www.europages.co.uk) which provide contact information for individual companies which can be approached directly for information.

Uses of plant products and processing activities

Information regarding processing procedures and flow diagrams were obtained from industry websites and text books describing processing in general (e.g. Hui, 2006) or processing for a specific sector (e.g. Bates, 2001). Review articles in journals were also useful in providing descriptions of processing activities. Due to the scarcity of data, examples of processes have been taken from around the world, and we assume that procedures will be similar for the particular pathways being studied in this project. There was not a great deal of literature describing the management of waste products from processing activities; such a topic is not normally of much significance in articles that describe the uses of a specific commodity. Nevertheless, literature describing management of apple waste was available, primarily due to the amount of waste generated from juicing activities. For more minor fruits, of which only a small proportion of total production is actually processed, such as plums, there was little information about the disposal of waste. However, like the waste from other fruits processing activities, it appears that such waste is used in animal feed or applied to land as a component of fertilizer or soil conditioner (see individual reports for details).

Conclusions

Sourcing data to provide input parameters for complex quantitative models is not straight forwards, particularly when the information or data comes from third parties, and has not been generated via carefully designed experiments whose purpose is to fill knowledge gaps and address data shortfalls in a specific model. Nevertheless, by searching widely, across a variety of media, both scientific and industrial, information has been obtained that allows quantitative parameters to be generated and used within the "general" and specific "consignment" models.

Commissioning original research to specifically generate data to address the largest uncertainties within models would improve confidence in the results produced.

3.1.2. Data sources, selection and extraction of pest-specific parameter values

Introduction

The project contract defined the case study pests as shown in Table 3.1.02 as the pests to be studied on particular example model pathways.

Table 3.1.02: Quantitative Pathway Analysis Lot 1, Food: Case study commodities

Commodity category	Pest	Common name	Product imported from case study countries
Pome fruit	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus	*Xanthomononas citri citri* (ex Hasse 1915) Gabriel et al 1989	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries).
Cereals	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

To inform parameterization of the pathway models for each pest-commodity combination, several types of information were collected. The information was used to provide the rationale for selecting the estimated values for several of the quantitative inputs required in the @Risk Excel models describing the likelihood of pest entry via selected case study pathways on one of four commodity types (Table 3.1.02). The aim of this report is to describe and discuss the data sources used with respect to the pests. Details of the sources used can be found in each of the complete pest-pathway reports. This report provides an overview of data gathering with some discussion.

Approach to data gathering

When searching for, and then using, data generated by other scientific studies, the method known as "systematic literature review" (SLR) is regarded as providing the highest level of evidence (level 1), whereas using descriptive studies and drawing on expert opinions represents level 7 (Higgins & Green, 2009). Using SLR is most appropriate when a large body of research work exists on a specific study question. SLR allows researchers to focus in on relevant studies from a pool of a larger body of work enabling the reviewers to address a very specific question. SLRs enable researchers to focus in on relevant material in an unbiased way, and the systematic approach to analysis adds credibility to research findings. Typically a conventional Cochrane-type systematic review would normally be expected to take 12 months (Higgins & Green, 2009). SLRs provide a rigorous and replicable method to identify, evaluate and summarise scientific evidence. The method originates in medicine in relation to disease treatments, disease prevention and diagnosis and was developed as a result of the need to identify, evaluate and summarise unmanageable quantities of public health research to aid decision makers.

The use of SLR for plant health purposes was used in the EFSA funded project *Prima phacie* (MacLeod *et al.*, 2012). However, the approach revealed that very often there is not a large body of literature on the plant health topics that were being investigated.

Given that the current project had to find many different types of information to inform values for model parameter estimates for four different pests and for four case study commodities (Table 3.1.02), for several steps along each pathway, there was no single narrow question that could be the subject of a SLR. Instead very many separate questions were required about the pests. For example, their distribution and life cycle within the area of pathway origin; how the pests are managed; how pests develop and survive at different temperatures. Thus it was not appropriate to use SLRs to collect data in this project. Instead, a systematic and structured technique for gathering information was used together with conventional literature searching techniques and subsequent "hand searching" (a tool also used in SLR).

Appendix F provides practical guidance for a systematic and structured technique for gathering information for pest risk analysis. The "decision tree" was developed for use by pest risk assessors at the Central Science Laboratory (CSL) which subsequently became the Food and Environment Research Agency (Fera). The tool is a useful guide to collect information commonly required in plant pest risk analysis and is designed assuming that the starting point is that a risk assessor is seeking information on a specific pest, a specific plant or plant product, or on a specific geographic area, typically a country. The information gathering "decision tree" systematically guides users to appropriate references as potential starting points for further data gathering. The references used during the search technique as well as useful websites are listed at the end of Appendix 6. Website links may not remain up to date.

Pest data sources

Four working papers, one for each case study commodity-pest pathway describe in detail the pathways and data sources from which model parameter values are derived. The four working papers are:

- Appendix A. Citrus (sweet oranges) with potential infestation by *Xanthomonas citri* pv. *citri*
- Appendix B. Pome fruit (apples) from USA and Canada with potential infestation by *Cydia prunivora*
- Appendix C. Stone fruit (plums) from USA or Canada with potential infestation by *Conotrachelus nenuphar*
- Appendix D. Wheat from South America and Oceania with potential infestation by *Listronotus bonariensis*

Each detailed working paper cites the data sources and literature from which information was collected. Very often the precise information or data values that were being sought as model input variables were not available and so some interpretation was necessary to convert what was available into appropriate model parameters for either a "general commodity model" or for a specific "consignment model" parameter. Sections 3.2 and 3.3 show how each model parameter was derived from the relevant commodity-pest pathway working paper.

This report outlines the searching technique and major data sources used with respect to the pest case studies.

Pest distribution and life cycle

To understand a potential pathway, some background knowledge of the pest is required. A good starting point is to find out about the pest's distribution in the area of origin; its life cycle and importance as a pest of the commodity concerned. The structured information gathering system (Appendix F) led to resources that provided such information. For example, descriptions of life cycles and the basic biology of pests and host plants are generally provided in older text books (e.g. Hill, 1983; Metcalf & Metcalf, 1993; Smith *et al.*, 1997) or in pest datasheets developed by extension services (e.g. Lienk, 1980) or organizations such as CABI (e.g. CABI, 2012).

Organism check lists, in the forms of books or online databases, provide information about geographic distribution of pests (e.g. Campbell *et al.*, 1989; Bousquet, 1991). For larger countries such as the USA and Canada, these sources and EPPO PQR (2014) also provide information about sub-national distribution so can support and fine-tune information reporting geographic distribution already collected. Online datasheets can be more easily revised so tend to be more up to date and accurate than older text books, especially regarding pest distribution.

Papers published in scientific journals can provide more detail about particular aspects of the biology of pests. Quite often it is older papers that provide such basic information (e.g. Armstrong, 1958;

Smith & Salkfeld, 1964; Levine & Hall, 1977). Reviews are useful for summarising large amounts of literature (e.g. Vincent *et al*., 1999). More recent papers make reference to older literature in their introductory sections so as to establish the framework within which the more recent work is being reported.

Pest Management

Having established an understanding of the pest and its biology in the area of origin, knowledge of the management practices used is required so as to inform the rate of pest infestation of the imported commodity. As noted above, the well-respected organization, CABI, provide information sheets for specific pests within their Crop Protection Compendium, available online via subscription. As well as other useful information the CABI pest datasheets list host plants and the particular growth stages affected. Symptoms and signs of infestation / infection are described allowing judgement regarding likelihood of the pest being found during export inspections. Detection and inspection methods are described, as are methods for prevention and control.

Literature searches using Google Scholar using key words such as pest name in combination with "control", "IPM" or "management" were used to find references describing pest control approaches (e.g. Prokopy *et al*., 2000).

Assessing the degree of crop infested at harvest was challenging for all pathways. However, it was fortunate that some research to specifically examine infestation at harvest was available for one of the case study pests (*Cydia prunivora* on apples). As reported in the apple-pathway report, *C. prunivora* was not regarded as a significant pest in North America and hence it was relatively little studied until Japan made it a quarantine pest in 1991, disrupting apple exports (Mantey *et al*., 2000). The organism increased its importance when Japan listed it as a quarantine pest. Subsequently a number of research projects were commissioned in North America to examine the biology of *C. prunivora* and to address pathway risks to Japan. Studies by Agnello *et al.* (2002, 2005) proved very useful in assessing the amount of apples infested at harvest by *C. prunivora*; these infestation rates were used in combination with estimates of in-transport survival described below to obtain an estimate of infestation rate on arrival at an EU port (Section 3.2 and 3.3).

Survival during transport and processing

Fresh plant products are often shipped in carefully controlled conditions. Information regarding methods of transport and conditions, particularly temperature and humidity, are available via cargo handlers websites e.g. Anon (2006), GDV (2014). It can be assumed that plant pests of phytosanitary concern are generally poikilotherms (not able to control or regulate their temperature, which is determined by the local environment and hence ambient). The temperatures experienced by pests infesting the commodity will be approximately the same as the ambient temperature at which the commodity is shipped.

Experiments describing the rate of pest development or survival at fixed temperatures are therefore useful for informing the likelihood of pest survival during transport of the commodity. The Journal of Economic Entomology has carried many papers describing development of specific pests at fixed temperatures. Data in such papers can be used to determine the threshold temperature for development (T_0) and the Degree Days (DD) required to complete development, either of a particular life stage, or for complete development (e.g. Neven, 2004; Selby & Whalon, 2014).

Information regarding commodity processing is described in the working paper for plant and commodity data sources. No literature could be found reporting results from experiments on case study invertebrate pests surviving processing activities.

Conclusions

Sourcing data to provide input parameters for complex quantitative models is not straight forwards, particularly when the information or data comes from third parties, and has not been generated via carefully designed experiments whose purpose is to fill knowledge gaps and address data shortfalls in a specific model. Nevertheless, by searching widely, across a variety of media, both scientific and industrial, information has been obtained that allows quantitative parameters to be generated and used within the "general" and specific "consignment" models.

The EU has commissioned specific projects to address knowledge gaps in pest risk assessments (e.g. Sansford *et al.*, 2006) Commissioning original research to specifically generate data to address pest and pathway risks is possible and would improve confidence in the risk assessment pathway models.

3.1.3. Additional data sources

Inter-country movement of commodities on an annual and monthly basis is broadly available from Eurostat databases: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

FAOStat database has also been used to get estimates of the annual inter-country trade within the EU: http://faostat.fao.org/site/291/default.aspx

The ESPON Data Navigator has been a useful pointer to national datasets relevant to domestic consumer and production indices: http://datanavigator.espon.eu/index.php

Full details of parameter searches for each of the case studies are given in Apppendices 1 to 4, inclusive. Table 3.1.03 lists parameter value search strategies for additional data sources not included in Appendices 1-4. These are provided in the sequence as used in the general model.

Table 3.1.03: EFSA QPAFood Search strategy for parameter values

Module: Parameter	Source/Search strategy	Values
Imports		
Imports by source country by month	Monthly data for recent calendar years drawn from HS6 codes in Eurostat Data Explorer http://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-016893_QID_-6B76D468_UID_-3F171EB0&layout=PERIOD,L,X,0;REPORTER,L,Y,0;PARTNER,L,Z,0;PRODUCT,C,Z,1;FLOW,L,Z,2;INDICATORS,C,Z,3;&zSelection=DS-016893PARTNER,EU28_EXTRA;DS-016893INDICATORS,VALUE_IN_EUROS;DS-016893FLOW,1;DS-016893PRODUCT,TOTAL;&rankName1=PARTNER_1_2_-1_2&rankName2=INDICATORS_1_2_-1_2&rankName3=FLOW_1_2_-1_2&rankName4=PRODUCT_1_2_-1_2&rankName5=PERIOD_1_0_0_0&rankName6=REPORTER_1_2_0_1&sortR=DND_-1&prRK=FIRST&prSO=PROTOCOL&pprRK=FIRST&pprSO=PROTOCOL&sortC=ASC_-1_FIRST&rLShi=0:2-26,27:0,29:1,28:29&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=ROLLING&time_most_recent=true&lang=EN&cfo=#,.&lang=en	Import values are in the database monthly for five years 2010-2014

	For aggregated commodities in Eurostat (such as stone fruits) the annual imports to key EU countries can be drawn from more disaggregated annual data in FAOStat and the proportion for the specific commodity can be applied to Eurostat values http://faostat3.fao.org/download/T/TP/E	
Imports by all sources by month	Monthly data for recent calendar years drawn from Eurostat Data Explorer as above Records to be drawn from the 261 individual countries in the Data Explorer list, excluding the aggregated regions	Import values are in the database monthly for five years 2010-2014
Production		
Market production by EU country by month	Annual data for recent years drawn from FAOStat and divided by 12 for monthly estimates of production at a national level for EU28 http://faostat3.fao.org/browse/Q/*/E	Annual production by commodity for EU28
Infested imports		
Infestation levels of imports into EU by country by month	Based on limits of contract terms and phytosanitary standards specified by EU fresh produce quality legislation (http://www.freshquality.eu/php/document.php?catdoc_id=59) May relate to unit size, such as apple size grades, which can be used to relate individual infested fruits within a consignment if "practically free of pests": http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050339	"practically free from pests" "the odd insect in a sample" So, say 1 infested apple in 150kg sample, @150g per apple, would be 1 infested apple in 1000 apples = 0.1% to 1 infested apple in 1500kg, 1/10000 apples or 0.01%
Infested transhipped		
Infestation levels of imports transhipped within EU by month	Calculated based on intra EU exports as a proportion of combined domestic production and primary importation to each EU MS	Monthly kg of infested commodity transhipped
Infested total		
Infestation levels of primary imports and transhipped commodity within EU by month	Calculated based on total of both primary imports and transhipped commodities within EU MS	Monthly kg of total infested commodity
Distribution of infested commodity		
Processing percentage of imports by	Processing percentage is related to the expected use of the product. Trade associations, such as Profel, are a source of such information. Price is an indicator, as	

country per month	only lower quality produce would enter low value processing, such as juicing. Values are derived from specific trade sources, with examples shown in case studies. The default for monthly processing proportion is expected to be the same throughout the year unless there is evidence to the contrary for any seasonal processing. Select spatial distribution based on human or livestock population or on domestic production areas by NUTS2.	
Percentage of processed imports that get processed in each NUTS2 region by month	This figure will default to a calculated value based on population and/or domestic production in the NUTS2 region unless there is specific evidence of locations where processing occurs.	Calculated
Retail waste stream	For fruits this is based on reports by WRAP. http://www.wrap.org.uk/sites/files/wrap/Resource_Map_Fruit_and_Veg_final_6_june_2011.fc479c40.10854.pdf http://www.wrap.org.uk/sites/files/wrap/WRAP%20Fruit%2015%20-%20final.pdf http://www.theguardian.com/global-development-professionals-network/2013/nov/07/stopping-the-rot-in-the-food-supply-chain http://www.wrap.org.uk/content/reducing-food-waste-extending-product-life Vanham, D., Bouraoui, F., Leip, A., Grizzetti, B., and Bidoglio, G. (2015) Lost water and nitrogen resources due to EU consumer food waste. Environ. Res. Lett. 10 (2015) 084008 doi:10.1088/1748-9326/10/8/084008	3% of fruit in retail is rejected as waste whole 97% of fruit is peeled and/or cored, with 20% going to an untreated waste stream 27% of apples bought by consumers are wasted whole : this may be a base value for other fruits stored in fruit bowls, where most waste occurs +/-20% variability on the means for retail (consumer) waste in fresh fruit is estimated based on potential for improvement on reducing waste by better home refrigeration Vanham et al. (2015) use an overall distribution for total fruit waste at consumer level across the EU as follows:

		Mean loss 0.255; Std dev 0.12; Max 0.41; Min 0.05
NUTS2 human population	Eurostat http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_r_d2jan&lang=en	Density, population/sq km
NUTS2 livestock equivalent	Eurostat http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=agr_r_animal&lang=en	Density, livestock unit/sq km
Percentage going to farm which is lost as whole grain unaffected by alimentary processes (Undigested)	http://www.omafra.gov.on.ca/english/crops/organic/news/2012/2012-10a2.htm http://www.nutrecocanada.com/docs/shur-gain---beef/finishing-cattle-on-whole-corn.pdf http://extension.psu.edu/animals/dairy/nutrition/nutrition-and-feeding/troubleshooting-guides/using-manure-evaluation-to-enhance-dairy-cattle-nutrition	Losses of grain as undigested following alimentary processes estimated at up to 0.5%
Vulnerability		
NUTS2 area	This is standard data for any run of the model; area data drawn from Eurostat http://ec.europa.eu/eurostat/en/web/products-datasets/-/TGS00002	Area in sq km
Commodity area by NUTS2	This data is commodity specific production area data by NUTS2 regions http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_popermreg&lang=en	Area in sq km
Vulnerability index by NUTS2: Average dispersal distance of pest per month under ideal conditions	Species specific dispersal data from general literature on the species of concern, CABI Crop Protection Compendium, EPPO pest list references, etc	Vulnerable area in sq km based on potential dispersal and density of host crop within the NUTS2 region
Contact		
Pest viability after processing use	This is a proportional value indicating pest survival after normal retail consumption. It reflects the part of the product on which the pest is present (which might affect survival with discarded portions, like peels or cores) and how discarded product is treated (such as composting, landfill, etc). Therefore, data is needed on which part of the product retains any infective pest material, and how that part is affected by processing or retail disposal.	Apples: Apples are sorted, washed, chopped and placed under high pressure at cool temperatures at a pressure of about 6 atmospheres, and then forced through a 100-150 mesh; unlikely for

	Specific pest biology in relation to hosts comes from general pest literature. Processing and disposal procedures can be found in manufacturing descriptions online. For juicing see http://www.fao.org/docrep/005/y2515e/y2515e00.htm See Appendices 1-3 sections on fruit processing review	insect survival, except for the sorted apples discarded prior to pressing (0-20% survival?) Oranges: Oranges are sorted, washed and pressed under low pressure; survival of insects in or pathogens in pulp and peel could be significant; survival in discarded oranges could be much higher (0-20% survival for insects?; 0-50% survival for fungal spores?) Plums: Plums are sorted, washed, heated to 50C for 10 minutes in the course of pressing for processing, unlikely for insect survival, except for discarded fruits (0-20% survival?)
Pest viability after retail use	This is a proportional value indicating pest survival after normal retail consumption. It reflects the part of the product on which the pest is present (which might affect survival with discarded portions, like peels or cores) and how discarded product is treated (such as composting, landfill, etc). Therefore, data is needed on which part of the product retains any infective pest material, and how that part is affected by processing or retail disposal. Specific pest biology in relation to hosts comes from general pest literature. While survival is expected to be greater after retail use there will not be great concentrations of waste, so it is less likely that a reproductive population could be established at any location. This might be particularly relevant in the case of insects in fruit where commercial quality standards mean that infestation levels would be expected to be extremely low and each consumer is unlikely to buy more than a few fruits at a time. See consumer waste: http://www.wrap.org.uk/sites/files/wrap/WRAP%20RTL044-001%20Final%20report.pdf See retail waste:	Consumer waste: 6.5% for apples; 5.0% for oranges Retail waste: 2-3% for apples; 2.0-2.5% for citrus

	http://www.wrap.org.uk/sites/files/wrap/Resource_Map_Fruit_and_Veg_final_6_june_2011.fc479c40.10854.pdf	
Retailed imports with viable pests	This is a calculation based on infested import volumes, proportion in retail chains and viability within the retail chain.	Weight of infested commodity by month by NUTS2 region
Vulnerable crop phenology by month	Phenological data estimates the probability of pest contact with susceptible hosts each month, assuming the presence of 100kg of infested material in contact with 1 ha of host crop. This is based primarily on host crop phenology, but could also involve infectivity or activity of the pest if that does not coincide with the crop phenology. A conservative estimate would be that contact could occur if there is a phenologically receptive host within dispersal distance of an infestation point. Contact could be proportionally lower based on the proportion of the host that is phenologically receptive and the extent of presence of the host crop within the dispersal radius. Crop specific phenology relevant to the stage at which pests can infest is required by country or by ecoregion within the EU. Multiple varieties with different phonological patterns may result in wider spread of contact probabilities over time, with greater variability within months. A comprehensive overview of the spatial and temporal variability of apple bud dormancy release and blooming phenology in Western Europe (Legave et al., 2013)	Northern European countries delayed by about one month compared to central Europe and have shorter season (estimated end 1 month earlier) Southern European countries start about one month earlier than central European countries. (Also estimated to end 1 month earlier due to dry summer conditions)
X.c.c. spread distances	X.c.c. Pathogen Dispersal: Most spread of canker by wind and rain is for short distances, i.e., within trees or to neighbouring trees. Canker develops more severely on the side of the tree exposed to wind-driven rain. Spread over longer distances, up to several miles, can result from severe meteorological events such as tropical storms, hurricanes, and tornadoes A recent study determined that 99% of infections that occur within a 30-day period are located within 594 m (1950 ft) of prior infected trees during normal weather conditions, i.e., when normal rain storms occur but tropical storms and hurricanes do not.. Hurricanes and tropical storms greatly increase citrus canker infection and can spread the bacteria over many miles. During 2004, Florida was subjected to three hurricanes that crossed and affected the majority of the commercial citrus industry. Bacterial dispersal gradients of up to 53 km (32 mi). http://www.apsnet.org/edcenter/intropp/lessons/prokaryotes/Pages/CitrusCanker.aspx	Min neighbouring tree, approx. 0.003km, most likely 600m, extreme maximum 53km

3.2. General model parameters

The sources of parameter values are described in Sections 3.1. Detailed justifications for the specific values used for each case study are given in Appendices A to D. General model parameters, units, values and variance are summarized for the four case studies in Tables 3.2.01 to 3.2.04, respectively.

Some missing values occur in the data sets used to build the models. For example certain data for particular months or particular NUTS2 regions was absent in a few cases. Assumptions have been made to allow the model to run with such data gaps and the values based on these assumptions are shown in yellow in the spreadsheets. Details of the assumptions made with respect to those parameters that have missing values are given at relevant points in Tables 3.2.01 to 3.2.04.

3.2.1. Oranges

Table 3.2.01: Variable value estimates – Parameterisation for sweet oranges potentially infested with Asiatic citrus canker, *Xanthomonas citri citri* (ex Hasse 1915) Gabriel et al 1989, from countries where this pest occurs

Parameter name	Parameter description	Units	Empirical background	Estimate	Distribution
Vol	Volume of Imports by Source Country by Month	100 Kg	Eurostat International trade data of imports of agricultural commodities from all the worlds countries (including the EU28) to the EU28	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Sweet Orange. MISSING VALUES: the Eurostat tables have gaps rather than specifically zeros; in the absence of a value, zero trade assumed.	Actual monthly data, or totals (expressed per year) for the sequence of years. (Effects of year to year differences to be examined in sensitivity analysis)
Inf%	Percentage Infestation levels of Imports by Country by Month	Units of commodity infested (%)	(Appendix A)#	0.0008% from US, Japan, S. Korea & S. America and 0.0042 % for other countries that are known sources. Zero for all other countries. Estimate is cumulative likelihoods of survival of harvest, packing and shipping	Effects of the relative difference between the two groups of countries to be examined in sensitivity analysis
CProd	Production of vulnerable commodity by Country by Month	Volume 100 Kg (converted from tonnes in FAOStat)	FAOStat national annual production data of agricultural	As accessed from FAOStat for period 2010 – 2014 for the commodity category Oranges	Actual yearly data, or totals (expressed per year) for the sequence of years.

			commodities from the EU28		
EUExtraExport	Volume of commodity export to nonEU28	Volume 100 Kg	Eurostat International trade data on export of agricultural commodities to countries outside the EU28	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Oranges.	Actual monthly data, or totals (expressed per year) for the sequence of years.
Proc%	Processing percentage by Country by Month	Volume of commodity processed (%)	(Appendix A) # Around 79% of the total supply is used for domestic consumption, with 17% used in the processing industry with the remainder being exported.	Most likely estimated at 17%	Variation between 10 and 25% used in the model to reflect the range of opinions that were sources. (See footnote#)
ProcN%	Location of processing by NUTS2 Region	Proportion of a countries processing in each region	Data on estimated number of fruit & vegetable processing enterprises in NUTS 2 regions in each Member State across the EU (Appendix A)	The proportion of enterprises in each NUTS2 region of each Member State. MISSING VALUES: There are a small number of data gaps. Where there is no country data, all NUTS2 regions in the country are assumed to have an equal proportion of processors. Where data for only some NUTS2 regions within a country are blank (rather than specifically zero) these are treated as zero.	The set of all fruit and vegetable food processing enterprises is expected to be larger than that for a specific commodity. To take account of this in the model, the proportion of enterprises is treated as the upper limit with a linear decline in probability of being some proportion lower than this. The modelled

					means therefore reflect the number of enterprises and the associated variances reflect uncertainty about which enterprises deal specifically with the commodity concerned.
Juiced%	Fraction of processing that involves juicing with associated pulp waste, by Country	Proportion involving juicing	Nearly all processing is juicing or part of a general processing stream of which juicing is an integral part (Appendix A)	Exact proportion not known but very high and 90% used. Same value used for all months and MS.	Min and Max used were 85%, and 95% to juicing but range not known
JWhole%	Whole fruit rejects from juicing	Proportion by country	UK resource map for fresh citrus supply (Terry et al., 2011) (Appendix A)#	3%. 3% of fruit rejected at post-import grading. Same value used for all MS.	Range unknown; +/- 20% used
JWholeLand%	Whole rejects to land application (juicing)	Proportion by country	Most processing waste goes to other uses, (Appendix A)#	Exact proportion not known but very low and 10% assumed	Range unknown; assumed that Min and Max of 0 and 20% goes to land application
JPeel%	Peel from juicing	Proportion by country	Peel about 50% (Appendix A)#	50%. About 50% of an orange is peel. Same value used for all MS.	Range unknown but amount of peel not expected to vary greatly; assumed +/- 10%.
JPeelLand%	Peel to land application from juicing	Proportion by country	Most processing waste goes to	Exact proportion not known but very low and 10%	Range unknown; assumed that

			other uses, (Appendix A)#	assumed. Same value used for all MS.	Min and Max of 0 and 20% goes to land application
JPulp%	Pulp from juicing	Proportion by country	Pulp after juicing depends on solid matter content which is about 10% (Appendix A)	Solid matter after juicing 10%. Same value used for all MS.	Range unknown; assumed +/- 20%.
JPulpLand%	Pulp to land application from juicing	Proportion by country	Most processing waste goes to other uses, (Appendix A)#	Exact proportion not known but very low and 10% assumed. Same value used for all MS.	Range unknown; assumed that Min and Max of 0 and 20% goes to land application
NJWhole%	Whole fruit rejects from non-juiced	Proportion by country	UK resource map for fresh citrus supply (Terry et al., 2011) (Appendix A)#	3%. 3% of fruit rejected at post-import grading. Same value used for all MS.	Range unknown; +/- 20% used
NJWholeLand%	Whole rejects to land application from Non-Juiced	Proportion by country	Most processing waste goes to other uses, (Appendix A)#	Exact proportion not known but very low and 10% assumed. Same value used for all MS.	Range unknown; assumed that Min and Max of 0 and 20% goes to land application
NJPeel%	Peel from non-juiced	Proportion by country	Peel about 50% (Appendix A)#	50%. About 50% of an orange is peel. Same value used for all MS.	Range unknown but amount of peel not expected to vary greatly; assumed +/- 10%.
NJPeelLand%	Peel to land application from non-juiced	Proportion by country	Most processing waste goes to other uses, (Appendix A)#	Exact proportion not known but very low and 10% assumed. Same value used for all MS.	Range unknown; assumed that Min and Max of 0 and 20% goes to land application
RWhole%	Whole rejects from retailed	Proportion	UK resource map for fresh citrus supply (Terry et al., 2011)	3%. 3% of fruit rejected at post-import grading. Same value used for all MS.	Range unknown; +/- 20% used

			(Appendix A)#		
RPeel%	Peel & core waste from retailed	Proportion	Peel about 50% (Appendix A)#	50%. About 50% of an orange is peel. Same value used for all MS.	Range unknown but amount of peel not expected to vary greatly; assumed +/- 10%.
Pop%	Annual Population data by NUTS2 (proportion in each NUTS2 region)	Numbers, 2009 - 2013	Eurostat national human population data	Most recent data available as accessed from Eurostat	Variance from year to year expected to be low at least in short term
Liv%	Annual Livestock Units by NUTS2 region	Numbers, 2009 - 2013	Eurostat national livestock numbers data	Most recent data available as accessed from Eurostat. MISSING VALUES: Data for Germany and Hungary are missing and an even distribution across NUTS2 regions within these countries was assumed	Variance from year to year expected to be low at least in short term
Host%	Commodity Area by NUTS2	Area occupied by vulnerable host (proportion of NUTS2 region)	Eurostat data on areas occupied by crop commodities	Data on areas occupied by vulnerable crop expressed as percentage of total area of NUTS2 region	Variance from year to year expected to be low at least in short term
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat data on areas of NUTS2 regions	As accessed from Eurostat	No variance
Foot%	Pest 'footprint': the area that the pest can reach in period they can survive after release from the imported	Area of footprint calculated from pest mobility (proportion of NUTS2 region)	99% of infections that occur within a 30-day period are located within 594m of prior infected trees during	Most likely 0.6km. Same value used for all MS.	Min neighbouring tree, approx. 0.003km, extreme maximum under European conditions estimated at

	commodity		normal weather conditions (Table 3.1.03.)		10km (Table 3.1.03.).
SurJWL%	Survival whole to land (juicing)	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) (Appendix A)	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max: 25%, 75%
SurlJWF%	Survival whole to feed (juicing)	Proportion	Zero, Feed processing kills pest (Appendix A)#	Estimated as zero. Same value used for all MS.	No variance
SurJPL%	Survival peel to land (juicing)	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) (Appendix A)	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max: 25%, 75%
SurJPF%	Survival peel to feed (juicing)	Proportion	Zero, Feed processing kills pest (Appendix A)#	Estimated as zero. Same value used for all MS.	No variance
SurJUL%	Survival pulp to land (juicing)	Proportion	Zero, Juice processing kills pest pest (Appendix A)#	Estimated as zero. Same value used for all MS.	No variance
SurJUF%	Survival pulp	Proportion	Zero, Juice	Estimated as zero.	No variance

	to feed (juicing)		processing kills pest pest (Appendix A)#	Same value used for all MS.	
SurNJWL%	Survival whole to land (non-juicing)	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) (Appendix A)	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max: 25%, 75%
SurNJWF%	Survival whole to feed (non-juicing)	Proportion	Zero, Feed processing kills pest. pest (Appendix A)#	Estimated as zero. Same value used for all MS.	No variance
SurNJPL%	Survival peel to land (non-juicing)	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) (Appendix A)	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max: 25%, 75%
SurNJPF%	Survival peel to feed (non-juicing)	Proportion	Zero, Feed processing kills pest (Appendix A)#	Estimated as zero. Same value used for all MS.	No variance
SurRW%	Survival retail whole waste	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max:

			periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) AAppendix A)		25%, 75%
SurRP%	Survival retail peel & pith to waste	Proportion	Survival good on host tissue; *X. citri* pv. citri can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald et al., 2002a; Graham et al., 2004) (Appendix A)	Estimated most likely 50%. Same value used for all MS.	Range unknown but may be quite variable: estimated Min and Max: 25%, 75%
Phen%	Proportion of hosts at allowing transfer by Country by Month	Proportion of host area in country	February to May and June to July highest risk periods (Appendix A)#	Relative cycle of phenological suitability based on timing of crop cycle and requirements of organism; with fully suitable (Phen% = 100%) and unsuitable (Phen% = 0) periods and a progressive change (0<Phen%<100%) from one to the other. Phenological suitability estimated separately for southern, central and northern zones of the EU	Range unknown: +/- 20% range of variation was assumed in the transition months between suitable and unsuitable periods

#Details of Empirical background where indicated in the table

Inf% Likelihood of infestation at harvest Studies by Ploper et al (2004) demonstrated the number of diseased fruit surviving culling at harvest to be <1%. However, considerable variation is likely day to day on and between orchards and the efficiency is likely to be much lower in orchards in Less Developed Countries. As a result, a conservative range would be from a minimum of ~1% for the best managed orchards in countries such as the US, Japan and S. American countries, to a maximum of around 5% for some smallholder operations in Less Developed Countries.

Epiphytic populations of *X. citri* pv. citri are likely to be present on fruit at harvest. Survival times of between three (Shiotani et al., 2009) and five (Belasque and Rodrigues-Neto, 2000) days have been reported.

Likelihood of infestation after packing station procedures The EFSA (2011) interpretation of the observations of Ploper et al (2004) suggest that with an initial infestation level of 1 and 3%, respectively the daily average of symptomatic fruit passing the inspection line is 0.0042%. Remaining infection levels at initial prevalence of diseased fruit of between 0.2 and 4% is 0.008 and 0.0042% whilst with an initial prevalence of <1% the remaining symptomatic fruit surviving the packing procedure will be up to 0.002%. Epiphytic bacterial levels on fruit surface reduced by 77-100% (Stapleton, 1986; Graham and Gottwald, 1991; Canteros 2004).

Likelihood of infestation after shipping Golmohammadi et al (2007) in 73% of imported citrus fruit showing canker lesions and between 12 and 61% of lesions on the fruit. No data are available for survival of epiphytic populations of *X. citri* pv. citri although packing station treatment reduce such populations by 77-100% and further loss of viability is likely during shipping. However, likely to be a lot of variation between packing stations within and between producer countries.

Proc% By far the greatest proportion of oranges used for domestic consumption and processing comes from the domestic production and internal trade from the main European citrus producers Spain, Italy, Greece, Portugal, and to a lesser extent, France. Oranges imported into the EU to fill shortfalls in domestic production represent, on average, only between 13 -14% of local production. In recent years import of oranges from third countries where *X. citri* pv. citri is endemic, account for only 1-2% of local production and 12-13% of total sweet orange imports. Around 79% of the total supply is used for domestic consumption, with 17% used in the processing industry with the remainder being exported. The EFSA Phyllosticta report has some information on imported fresh citrus fruit being used in processing. The figures in Table 37 of that report have a median figure of 20%, a minimum 15% and 25 %maximum. These figure come from a single source – a personal opinion of a Dr Forner from a Spanish research institute. This compares with figure of 10% initially used in the model based on based on two separate conversations with industry professionals. So neither opinion is supported by any readily available published information. Model amended to encompass the wider range from 10% to 25% with a mode of 17%.

JWhole% Estimated fresh citrus losses of 3% during post-import grading and inspection, 0.1-0.5% during packing and 2-2.5% during retail are reported along the supply chain to the point of sale. Additional losses, estimated at 2.8% of the total supply for fresh orange for 2012, are the result of household waste after purchase (Quested, 2013).

JWholeLand%, JPeel%, JPeelLand% Ultimately, approximately 50% of an orange is discarded as peel in households. This will either enter the general waste stream ending up as landfill or be used for composting along with the general food waste. Peel from oranges used in processing will either be used for cattle feed either directly or after extraction of useful chemicals.

SurJPF% and survival on other processing routes It is unlikely that *X. citri* pv. citri would survive during processing because of the chemical processes and heating required to produce the final product. The main risk in the processing operation would be the initial washing step before processing commences. Any bacteria in cankers on infected fruit are likely to enter the wash water and be discharged into waterways directly or after passing through a sewage treatment plant. It is not possible to either estimate the probable level of infection of oranges arriving at the processing plant or the potential of the pathogen to survive the washing procedure. No data on survival of xanthomonads in water could be found and it is not possible to predict their ability to survive for long periods in water.

Phen% At temperatures favourable for disease development (25-35°C), it is feasible that bacteria could be transferred from discarded diseased fruit close to domestically or commercially growing citrus. Infections could occur and spread rapidly at warm temperatures, with prolonged rain or overhead irrigation, when trees are in a susceptible stage of development for infection to occur. This is principally in the spring, summer and autumn growth flushes

3.2.2. Apples

Table 3.2.02: Variable value estimates – Parameterisation for import of Dessert Apples from USA and Canada having potential infestation with the pest, lesser apple worm, *Cydia prunivora*

Parameter name	Parameter description	Units	Empirical background	Estimate	Distribution
Vol	Volume of Imports by Source Country by Month	100 Kg	Eurostat International trade data of imports of agricultural commodities from all the worlds countries (including the EU28) to the EU28	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Fresh Apple. MISSING VALUES: the Eurostat tables have gaps rather than specifically zeros; in the absence of a value, zero trade assumed.	Actual monthly data, or totals (expressed per year) for the sequence of years. (Effects of year to year differences to be examined in sensitivity analysis)
Inf%	Percentage Infestation levels of Imports by Country by Month	Units of commodity infested (%)	Taking into account at-harvest infestation and shipment survival (Appendix B)#. Min and most likely values both zero and max approximately 0.0034%.	Most likely value zero. Mean of distribution used was 0.00057%. Estimate is cumulative likelihoods of survival of harvest, packing and shipping. Same value used for all sources.	Effects of differences in infestation rate between the two source-countries to be examined in sensitivity analysis.
Cprod	Production of vulnerable commodity by Country by Month	Volume 100 Kg (converted from tonnes in FAOSTAT)	FAOSTAT national annual production data of agricultural commodities from EU28	As accessed from FAOStat for period 2010 – 2014 for the commodity category Apple	Actual yearly data, or totals (expressed per year) for the sequence of years.
EUExtraExport	Volume of commodity export to nonEU28	Volume 100 Kg	Eurostat International trade data on export of agricultural commodities to countries	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Fresh Apple.	Actual monthly data, or totals (expressed per year) for the sequence of years.

			outside EU28		
Proc%	Processing percentage by Country by Month	Volume of commodity processed (%)	(Appendix B) Bates *et al.* (2001) estimated around 20% of dessert apples are used for processing. More recently Krautgartner *et al.* (2013) estimated 24.5% to 27.3% of total EU apple supply was used for processing. Based on such information, it is reasonable to assume that a maximum of between 20% and 27% of imported N American apples are used for processing.”)	A modal value of 23.5% used for all countries except where country-specific data were found: France, 2% and Hungary, 60% (Appendix B , Section 22)	Min and max values used for all countries were 20% and 27% (range based on the range of values reported in different studies) Ranges for France 1.5% to 2.5% and Hungary 40% to 65% are judgements by the authors.
ProcN%	Location of processing by NUTS2 Region	Proportion of a countries processing in each region	Data on numbers of food processing enterprises by NUTS2 region (Appendix B, tabulated data: Appendix B)	The proportion of enterprises in each NUTS2 region of each Member State. MISSING VALUES: There are a small number of data gaps. Where there is no country data, all NUTS2 regions in the country are assumed to have an equal proportion of processors. Where data for only some NUTS2	The set of all fruit and vegetable food processing enterprises is expected to be larger than that for a specific commodity. To take account of this in the model, the proportion of enterprises is treated as the upper limit with a linear decline in probability of being some proportion lower

				regions within a country are blank (rather than specifically zero) these are treated as zero.	than this. The modelled means therefore reflect the number of enterprises and the associated variances reflect uncertainty about which enterprises deal specifically with the commodity concerned.
Juiced%	Fraction of processing that involves juicing with associated pulp waste, by Country	Proportion involving juicing	Appendix B, US Apple, 2011, indicates that 14.4% of total apple production (46.9% of processed production) is used for juice and the remainder for canning, drying, freezing, slicing and "other", Bates et al., 2001)[#].	46.9%. Same value used for all months and MS	Range unknown +/- 20% was used.
JWhole%	Whole fruit rejects from juicing	Proportion by country	3% of fruit in retail is rejected as waste whole (Table 3.1.03).	3%. Same value used for all months and MS	Range unknown, +/- 20% was used
JWholeLand %	Whole rejects to land application (juicing)	Proportion by country	Dhillon et al. (2012) (for Canada) : 20% of waste goes to animal feed, 80% goes to land application (composting or land fill) (Appendix B)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
JPeel%	Peel from juicing	Proportion by country	Apples not peeled prior to processing.	Zero. Same value used for all months and MS	Not applicable

			Brandt & Martin (1994) provide detailed flow diagrams for the processing of apples into apple juice, apple sauce and apple slices and includes points in processing chains where "waste" is disposed of into other uses.		
JPeelLand%	Peel to land application from juicing	Proportion by country	Apples not peeled prior to processing.	Zero. Same value used for all months and MS	Not applicable
JPulp%	Pulp from juicing	Proportion by country	Solid matter after juicing 25% (Appendix B) Recent review by Shalini & Gupta (2010) still suggests that juicing produces around 25% waste.	25%. Same value used for all months and MS.	Range unknown, +/- 20% used.
JPulpLand%	Pulp to land application from juicing	Proportion by country	Dhillon et al. (2012) (for Canada): 20% of waste goes to animal feed, 80% goes to land application (composting or land fill) (Appendix B)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
NJWhole%	Whole fruit rejects from non-juiced	Proportion by country	3% of fruit in retail is rejected as waste whole (Table 3.1.03).	3%. Same value used for all months and MS	Range unknown, +/- 20% was used

NJWholeLand%	Whole rejects to land application from Non-Juiced	Proportion by country	Dhillon et al. (2012) (for Canada) : 20% of waste goes to animal feed, 80% goes to land application (composting or land fill) (Appendix B)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
NJPeel%	Peel from non-juiced	Proportion by country	97% of fruit is peeled and/or cored, with 20% going to an untreated waste stream. (Based on reports by WRAP, see Table 3.1.03)	20% used for all months and MS	Range unknown, +/- 20% used
NJPeelLand%	Peel to land application from non-juiced	Proportion by country	Dhillon et al. (2012) (for Canada) : 20% of waste goes to animal feed, 80% goes to land application (composting or land fill) (Appendix B)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
RWhole%	Whole rejects from retailed	Proportion	27% of apples bought by consumers are wasted whole: this may be base value for fruits stored in fruit bowls, where most waste occurs but many apples refrigerated reducing losses. (Table 3.1.03).	20% of fruit is rejected whole by consumer. Same value used for all months and MS	Range unknown, +/- 20% used
RPeel%	Peel & core	Proportion	97% of fruit	20% used for all	Range unknown,

	waste from retailed		is peeled and/or cored, with 20% going to an untreated waste stream. (Based on reports by WRAP, see Table 3.1.03)	months and MS	+/- 20% used
Pop%	Annual Population data by NUTS2 (proportion in each NUTS2 region)	Numbers, 2009 - 2013	Eurostat national human population data	Most recent data available as accessed from Eurostat	Variance from year to year expected to be low at least in short term
Liv%	Annual Livestock Units by NUTS2 region	Numbers, 2009 - 2013	Eurostat national livestock numbers data	Most recent data available as accessed from Eurostat. MISSING VALUES: Data for Germany and Hungary are missing and an even distribution across NUTS2 regions within these countries was assumed	Variance from year to year expected to be low at least in short term
Host%	Commodity Area by NUTS2	Area occupied by vulnerable host (proportion of NUTS2 region)	Eurostat data on areas occupied by crop commodities	Data on areas occupied by vulnerable crop expressed as percentage of total area of NUTS2 region	Variance from year to year expected to be low at least in short term
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat data on areas of NUTS2 regions	As accessed from Eurostat	No variance
Foot%	Pest 'footprint': the area that the pest can reach in period they can survive after release	Area of footprint calculated from pest mobility (proportion of NUTS2	Area of a circle with radius equal to the average flight distances of *C. prunivora* in lifetime or	Most likely values of 0.5km used. Same value used for all months and MS	A range from 0 to 5 km used

	from the imported commodity	region)	in 1 month (whichever is the lesser). Appendix B, Min = 0m, most likely = less than 800m, max = 3km (or 8km but very rare).		
SurJWL%	Survival whole to land (juicing)	Proportion	Appendix B, Possible that up to 20% survive composting#	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
SurlJWF%	Survival whole to feed (juicing)	Proportion	Zero, Feed processing using mechanical, heat, chemical or ensiling kills pest#	Estimated as zero. Same value used for all MS.	No variance
SurJPL%	Survival peel to land (juicing)	Proportion	High larval physical damage due to mechanical processes expected prior to composting, (Appendix B)#	2% survival estimated	High variability expected. Range from 0 to 4% used
SurJPF%	Survival peel to feed (juicing)	Proportion	Zero, Feed processing using mechanical, heat, chemical or ensiling kills pest#	Estimated as zero. Same value used for all MS.	No variance
SurJUL%	Survival pulp to land (juicing)	Proportion	Zero, Feed processing using mechanical, heat, chemical or ensiling kills pest#	Estimated as zero. Same value used for all MS.	No variance
SurJUF%	Survival pulp to feed (juicing)	Proportion	Zero, Feed processing using mechanical,	Estimated as zero. Same value used for all MS.	No variance

			heat, chemical or ensiling kills pest#		
SurNJWL%	Survival whole to land (non-juicing)	Proportion	Appendix B, Possible that up to 20% survive composting#	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
SurNJWF%	Survival whole to feed (non-juicing)	Proportion	Zero, Feed processing using mechanical, heat, chemical or ensiling kills pest#	Estimated as zero. Same value used for all MS.	No variance
SurNJPL%	Survival peel to land (non-juicing)	Proportion	High larval physical damage due to mechanical processes expected prior to composting, (Appendix B)#	2% survival estimated	High variability expected. Range from 0 to 4% used
SurNJPF%	Survival peel to feed (non-juicing)	Proportion	Zero, Feed processing using mechanical, heat, chemical or ensiling kills pest#	Estimated as zero. Same value used for all MS.	No variance
SurRW%	Survival retail whole waste	Proportion	Appendix B, Possible that up to 20% survive composting#	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
SurRP%	Survival retail peel & core waste	Proportion	Appendix B, Possible that up to 20% survive composting#	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
Phen%	Proportion of hosts at allowing transfer by Country by Month	Proportion of host area in country	Months in which crop vulnerable to pest taken from crop phenologies in northern, central & southern	Relative cycle of phenological suitability based on timing of crop cycle and requirements of organism; with fully suitable (Phen% = 100%)	Range unknown: +/- 20% range of variation was assumed in the transition months between suitable and unsuitable periods

			Europe (Appendix B; Table 3.1.03). Both crop suitable and pest dispersal conditions suitable: Jun-Sept (northern), May-Oct (central) and Apr-Sep (southern)	and unsuitable (Phen% = 0) periods and a progressive change (0<Phen%<100 %) from one to the other. Phenological suitability estimated separately for southern, central and northern zones of EU	

[#]Details of Empirical background where indicated in the table

Inf% Likelihood of infestation at harvest In studies by Agnello et al. over 4 years, at least 50% of orchards studied had no damage from internal Lepidoptera each year (mean value over 4 years is 74% ((8/16)+(6/16+(7/16)+(2/16))/4). Standard grower practice resulted in mean infestation of 0.11% ((0.27+0.11+0.02+0.02)/4). Hence possible input parameter has a probability distribution function (pdf) with 50% (or 74%) being 0 and the remaining % having a mean of 0.11%. However, this would represent the likelihood of a harvested apple being infested by one of three species. Two of which are more abundant than the case study pest. If all Lepidoptera were equally abundant one could divide the above likelihood by 3. (0.11% / 3 = 0.0366%). This would still overestimate the likelihood of infestation by C. prunivora. Assuming only 20% of any infestation was due to *C. prunivora* would seem reasonable, hence divide 0.11% by 5 (0.11/5= 0.022%). 74% with infestation of zero and 26% with average infestation of 0.022% gives a mean infestation rate of (0.74 x 0) + (0.26 x 0.00022) = 0.0000572 (this is the mean not the most likely).

Likelihood of avoiding detection during harvest and export checks No studies have been found that quantify the likelihood of pickers detecting infested fruit but apples infested with *C. prunivora* show symptoms that are usually visible to the naked eye (CABI, CPC 2012) and hence will avoid harvesting them for export. Conclusion: An estimate of the likelihood of infested fruit escaping detection and proceeding along the pathway is needed. Given trained pickers are used, fruit is then graded then inspected by NPPO officials to certify fruit meets export quality, and all the while symptoms are visible to the naked eye, is it reasonable to assume that only infestation at most below 0.5% remains undetected. Hence assuming mean infestation was 0.022%, export checks do not reduce the level of infestation (to detect 0.1% infestation with 95% confidence, 950 of 1000 lots would need to be sampled)

An estimate of the likelihood of infested fruit remaining infested after shipping A conservative estimate would be to assume apples are in cold storage for 40 days, during which 99% of stage 1 eggs will suffer mortality and at least 90% of stage 2 and stage 3 eggs will suffer mortality (Table 4). More than 90% of eggs that hatch will die as 1st instar larvae (Table 5). 90% of 2nd and 3rd instar larvae already in the apple fruit will also die after 40 days in cold storage. Conclusion: A conservative estimate is that 90% of fruit that were infested remain infested after 40 days.

Juiced% No EU data could be found describing the utilization of apples for processing in Europe. However, the US Apple Association produced a market analysis of US production in 2011 and reported 67.7% of apples were consumed fresh, 14.4% used for juicing, 11.2% canned, 1.9% frozen, 1.8% dried, 1.4% fresh sliced and 0.8% were not marketed (USApple, 2011). [Calculation: Juiced%/Other processing%]

JWholeLand% Of the volume of apples going to processing, the majority of which is for apple juice, a mass of 25% is produced as waste. % larval survival during processing = ? No data available. Assuming that some larvae can survive, we need an estimate of the volume processed further.

Adapted figures in Dhillon et al. (2012) (for Canada) thus 20% of waste goes to animal feed and 80% goes to land application (composting or land fill). Any pests in pomace waste that is incinerated will be killed.

JPeel% Brandt & Martin (1994) provide more detailed flow diagrams for the processing of apples into apple juice, apple sauce and apple slices and includes points in the processing chains where "waste" is disposed of into other uses. All three processing systems lead either to waste being used for animal feed or being returned to land, e.g. as either land fill or as a soil improver. It is reasonable to assume that the processing of apples into products other than juice, sauce or slices also results in waste either being routed to animal feed or back to land.

SurJWL%, SurJPL% An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via land application (based on Table A2.26.01, Appendix B Section 26) In landfill, a small fraction will survive. If near the surface of the landfill, birds will feed on waste fruit / pomace, rotting fruit will degrade inhibiting larval development. If buried within landfill, emerging adults will not escape. Composting, as in previous estimate, survival in poorly managed composting system may be higher, 20% may be reasonable guess.

SurlJWF% An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via animal feed according to method of treatment (based on Table A2.26.01, Appendix B) Mechanical = 0% survival, Heat = 0% survival, Chemical = 0% survival, Ensiling = 0% survival.

3.2.3. Plums

Table 3.2.02: Variable value estimates - Parameterization for import of Plums from USA and Canada having potential infestation with the pest, Plum weevil *Conotrachelus nenuphar* (Herbst)

Ref	Parameter description	Units	Empirical background	Estimate	Distribution
Vol	Volume of Imports by Source Country by Month	100 Kg	Eurostat International trade data of imports of agricultural commodities from all the worlds countries (including the EU28) to the EU28	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category stone fruit. MISSING VALUES: the Eurostat tables have gaps rather than specifically zeros; in the absence of a value, zero trade assumed.	Actual monthly data, or totals (expressed per year) for the sequence of years. (Effects of year to year differences to be examined in sensitivity analysis)
Inf%	Percentage Infestation levels of Imports by Country by Month	Units of commodity infested (%)	At harvest, distribution with min and most likely values both zero and max 0.1% (giving mean of 0.0167%); In-shipment survival can be between 0 and 100%, estimated 10%. (Appendix C)	Most likely value zero. Mean of distribution used was 0.0167%. Estimate is cumulative likelihoods of survival of harvest, packing and shipping. Same value used for all sources.	Effects of differences in infestation rate between the two source-countries to be examined in sensitivity analysis.
Cprod	Production of vulnerable commodity by Country by Month	Volume 100 Kg (converted from tonnes in FAOSTAT)	FAOSTAT national annual production data of agricultural commodities from the EU28	As accessed from FAOStat for period 2010 – 2014 for the commodity category Stone fruits (Apricots, cherries, peaches, nectarines, plums and sloes)	Actual yearly data, or totals (expressed per year) for the sequence of years.
EUExtraExport	Volume of commodity export to	Volume 100 Kg	Eurostat International trade data	As accessed from Eurostat for period Jan 2010 – Dec	Actual monthly data, or totals (expressed per

	nonEU28		on export of agricultural commodities to countries outside the EU28	2014 for the commodity category Stone fruits	year) for the sequence of years.
Proc%	Processing percentage by Country by Month	Volume of commodity processed (%)	5% Assumed that 95% of imported plums are consumed as fresh fruit (as per Meijer et al., 2013) and 5% are used for processing. (Appendix C).	5%. Same value used for all months and MS	Range unknown +/- 20% was used.
ProcN%	Location of processing by NUTS2 Region	Proportion of a countries processing in each region	Data on numbers of food processing enterprises by NUTS2 region (Appendix B)	The proportion of enterprises in each NUTS2 region of each Member State. MISSING VALUES: There are a small number of data gaps. Where there is no country data, all NUTS2 regions in the country are assumed to have an equal proportion of processors. Where data for only some NUTS2 regions within a country are blank (rather than specifically zero) these are treated as zero.	The set of all fruit and vegetable food processing enterprises is expected to be larger than that for a specific commodity. To take account of this in the model, the proportion of enterprises is treated as the upper limit with a linear decline in probability of being some proportion lower than this. The modelled means therefore reflect the number of enterprises and the associated variances reflect uncertainty about which enterprises deal specifically with the commodity concerned.
Juiced%	Fraction of	Proportion	The extent of	Value not known.	Range unknown

	processing that involves juicing with associated pulp waste, by Country	involving juicing	juicing of plums and prunes in relation to other uses not known but expected to be low compared to apple and orange (Appendix C).	10% estimated. Same value used for all months and MS	+/- 20% was used.
JWhole%	Whole fruit rejects from juicing	Proportion by country	3% of fruit in retail is rejected as waste whole (Table 3.1.03).	3%. Same value used for all months and MS	Range unknown, +/- 20% was used
JWholeLand%	Whole rejects to land application (juicing)	Proportion by country	In a review by Dhillon et al. (2013) 80% of apple pomace was disposed of via composting, landfill or incinerated. It is reasonable to assume that a similar proportion of plum pomace may also be disposed of in this way (Appendix C)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
JPeel%	Peel from juicing	Proportion by country	Plums not peeled prior to processing. Detailed flow diagrams for the processing of plums into juice includes points in the processing chains where "waste" is disposed of	Zero. Same value used for all months and MS	Not applicable

			into other uses (Appendix C).		
JPeelLand %	Peel to land application from juicing	Proportion by country	Plums not peeled prior to processing.	Zero. Same value used for all months and MS	Not applicable
JPulp%	Pulp from juicing	Proportion by country	Approximately 58% of the fresh weight of a plum is pulp or pomace (Dwivedi 2012). (Appendix C)	58%. Same value used for all months and MS	Range unknown, +/- 20% was used
JPulpLand %	Pulp to land application from juicing	Proportion by country	80% (Appendix C)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
NJWhole %	Whole fruit rejects from non-juiced	Proportion by country	3% of fruit in retail is rejected as waste whole (Table 3.1.03).	3%. Same value used for all months and MS	Range unknown, +/- 20% was used
NJWholeLand%	Whole rejects to land application from Non-Juiced	Proportion by country	80% (Appendix C)	80%. Same value used for all months and MS	Range unknown, +/- 20% was used
NJPeel%	Peel from non-juiced	Proportion by country	Plums not peeled prior to processing. (The pit represents 3, 3.8, 4.9 % (min, average, max) of the fruit weight, MacLeod pers. comm.)	Zero (for peel). Same value used for all months and MS	Not applicable
NJPeelLand%	Peel to land application from non-juiced	Proportion by country	Plums not peeled prior to processing. Pit 100% assumed as unsuitable for other uses	Zero (for peel). Same value used for all months and MS	Not applicable

RWhole%	Whole rejects from retailed	Proportion	3% of fruit in retail is rejected as waste whole (Table 3.1.03).	3%. Same value used for all months and MS	Range unknown, +/- 20% was used
RPeel%	Peel & core waste from retailed	Proportion	Plums not peeled prior to consumption. Pit 100% assumed waste.	Zero (for peel). Same value used for all months and MS	Not applicable
Pop%	Annual Population data by NUTS2 (proportion in each NUTS2 region)	Numbers, 2009 - 2013	Eurostat national human population data	Most recent data available as accessed from Eurostat	Variance from year to year expected to be low at least in short term
Liv%	Annual Livestock Units by NUTS2 region	Numbers, 2009 - 2013	Eurostat national livestock numbers data	Most recent data available as accessed from Eurostat. MISSING VALUES: Data for Germany and Hungary are missing and an even distribution across NUTS2 regions within these countries was assumed	Variance from year to year expected to be low at least in short term
Host%	Commodity Area by NUTS2	Area occupied by vulnerable host (proportion of NUTS2 region)	Eurostat data on areas occupied by crop commodities	Data on areas occupied by vulnerable crop expressed as percentage of total area of NUTS2 region	Variance from year to year expected to be low at least in short term
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat data on areas of NUTS2 regions	As accessed from Eurostat	No variance
Foot%	Pest 'footprint': the area that the pest can reach in period they can survive after release	Area of footprint calculated from pest mobility (proportion of NUTS2 region)	Area of a circle with radius equal to the average flight distances of *Conotrachelu*	Most likely values of 2km used. Same value used for all months and MS	A range from 1 to 8km used

	from the imported commodity		*s nenuphar* in lifetime or in 1 month (whichever is the lesser): Min = 1km, Most likely = 2km, Max = 8km (Appendix C)		
SurJWL%	Survival whole to land (juicing)	Proportion	Appendix C, Possible that up to 20% survive composting	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
SurlJWF%	Survival whole to feed (juicing)	Proportion	Processing of plum pomace is likely to employ mechanical, heat, chemical or ensiling methods (Harpster et al., 1993; Brandt & Martin, 1994) all very likely to kill the pest (Appendix C)	Estimated as zero. Same value used for all MS.	No variance
SurJPL%	Survival peel to land (juicing)	Proportion	Plums not peeled prior to processing.	Not applicable	Not applicable
SurJPF%	Survival peel to feed (juicing)	Proportion	Plums not peeled prior to processing.	Not applicable	Not applicable
SurJUL%	Survival pulp to land (juicing)	Proportion	Processing of plum pomace is likely to employ mechanical, heat, chemical or ensiling methods (Harpster et al., 1993; Brandt & Martin, 1994)	Estimated as zero. Same value used for all MS.	No variance

			all very likely to kill the pest (Appendix C)		
SurJUF%	Survival pulp to feed (juicing)	Proportion	Processing of plum pomace is likely to employ mechanical, heat, chemical or ensiling methods (Harpster et al., 1993; Brandt & Martin, 1994) all very likely to kill the pest (Appendix C)	Estimated as zero. Same value used for all MS.	No variance
SurNJWL %	Survival whole to land (non-juicing)	Proportion	Appendix C, Possible that up to 20% survive composting	Most likely value of 10% used. Same value used for all months and MS	High variability expected and a range of 0 to 20% was used
SurNJWF %	Survival whole to feed (non-juicing)	Proportion	Processing of plum pomace is likely to employ mechanical, heat, chemical or ensiling methods (Harpster et al., 1993; Brandt & Martin, 1994) all very likely to kill the pest (Appendix C)	Estimated as zero. Same value used for all MS.	No variance
SurNJPL%	Survival peel to land (non-juicing)	Proportion	Plums not peeled prior to processing.	Not applicable	Not applicable
SurNJPF%	Survival peel to feed (non-juicing)	Proportion	Plums not peeled prior to processing.	Not applicable	Not applicable
SurRW%	Survival retail whole waste	Proportion	Appendix C, Possible that	Most likely value of 10% used. Same	High variability expected and a

			up to 20% survive composting	value used for all months and MS	range of 0 to 20% was used
SurRP%	Survival retail peel & core waste	Proportion	Plums not peeled prior to processing.	Not applicable	Not applicable
Phen%	Proportion of hosts at allowing transfer by Country by Month	Proportion of host area in country	Months in which crop vulnerable to pest taken from crop phenologies in northern, central & southern Europe (Appendix C). Both crop suitable and pest dispersal conditions suitable: May to August (northern), April to September (central) and March to November (southern) (Appendix C)	Relative cycle of phenological suitability based on timing of crop cycle and requirements of organism; with fully suitable (Phen% = 100%) and unsuitable (Phen% = 0) periods and a progressive change (0<Phen%<100%) from one to the other. Phenological suitability estimated separately for southern, central and northern zones of the EU	Range unknown: +/- 20% range of variation was assumed in the transition months between suitable and unsuitable periods

3.2.4. Wheat

Table 3.2.04: Variable value estimates – Parameterisation for imports of wheat from Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand having potential infestation with the pest, Argentine stem weevil, *Listronotus bonariensis* (Kuschel)

Ref	Parameter description	Units	Empirical background	Estimate	Distribution
Vol	Volume of Imports by Source Country by Month	100 Kg	Eurostat International trade data of imports of agricultural commodities from all the worlds countries	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Wheat. MISSING VALUES: the	Actual monthly data, or totals (expressed per year) for the sequence of years.

			(including EU28) to EU28	Eurostat tables have gaps rather than specifically zeros; in the absence of a value, zero trade assumed.	(Effects of year to year differences to be examined in sensitivity analysis)
Inf%	Percentage Infestation levels of Imports by Country by Month	Units of commodity infested (%)	Detection unlikely below 0.5% but max infestation rate likely to be lower. Min, most likely, max estimated at 0, 0, 0.5, making a mean of 0.08%. Calculated from farm gate infestation combined with in-shipment survival estimates AppendixD4.	Mean valued calculated from distribution 0.08% Estimate is cumulative likelihoods of survival of harvest, packing and shipping. Same value used for all source countries.	Effects of the relative difference between the two clusters of countries (South America and Australasia) to be examined in sensitivity analysis
CProd	Production of vulnerable commodity by Country by Month	Volume 100 Kg (converted from tonnes in FAOSTAT)	FAOSTAT national annual production data of agricultural commodities from the EU28	As accessed from FAOStat for period 2010 – 2014 for the commodity category Wheat	Actual yearly data, or totals (expressed per year) for the sequence of years.
EUExtraExport	Volume of commodity export to nonEU28	Volume 100 Kg	Eurostat International trade data on export of agricultural commodities to countries outside the EU28	As accessed from Eurostat for period Jan 2010 – Dec 2014 for the commodity category Wheat (code 041).	Actual monthly data, or totals (expressed per year) for the sequence of years.
Port%	Potentially – infested Imports by NUTS 2 location of the Port of entry	Proportion of EU imports entering each NUTS2	Import volumes by Port (Appendix D)	Percentage of volume entering the ports in each NUTS2 region	Actual yearly data, or totals (expressed per year) for the sequence of years. for the period 2010 to 2013
PortLoss%	Grain losses at port	Proportion	Minimum and maximum	Mid-point of 0.4% estimated as	Range from 0.2 to 0.6%

			estimates of losses during unloading of grain shipments are 0.2 and 0.6% (Appendix D)	most likely. Same values used for all months and MS.	used.
ToMills%	Percentage of grain going to Mills rather than industrial uses by Country by Month	Proportion	Supply and usage of wheat in the EU 2010-2014 ('000 mt), EU Cereals Supply and Demand, European Commission, Directorate General for Agriculture and Rural development (Appendix D)	Uses of wheat: 91% to mills for human consumption and animal feed. Same values used for all months and MS.	Variability based on year to year variation 2010 to 2014. Approximately +/- 2%
MillN%	Milling in each NUTS2	Proportion	Number of manufacturers of grain and mill products (Appendix D). Correlation with wheat production (Appendix D) used to estimate location of mills by NUTS2 ('Mills by NUTS2', QPA General Model wheat Module2)	Numbers of mill enterprises in each NUTS2 giving estimate of proportion of milling activity in each NUTS of each MS	Actual data used. No estimate of potential variation.
FeedG%	Percentage going to whole grain feed at mill	Proportion	Uses of wheat, Appendix D[#]	5% No information about proportion of grain to feed that is used as whole grain. Known to be some and small proportion expected. Same values used for all months and MS.	Range unknown; +/- 20% used
FeedM%	Percentage going to milled feed at mill	Proportion	Uses of wheat, Appendix D[#]	46%. Same values used for all months and MS.	Year to year variation between 2010/2011 and

					2013/2014, approximately +/- 2%, used
MillLoss%	Grain losses during milling/en route to milling	Proportion	Appendix D: Spillage of wheat grain and mortality of *L. bonariensis* after arrival at destination	Losses expected to be slightly higher than those at port due to greater handing during these processes, 0.5% used as mean and most likely value. Same values used for all months and MS.	Range unknown but assumed similar to variability to port, 0.25 to 0.75% assumed
IndN%	Industrial / bioethanol used in each NUTS2	Proportion	Location of Industrial losses attributed to NUTS2 region categorized under NACE code 20.14, manufacturing of organic based chemicals (including bio-refineries) (Appendix D), ('Other by NUTS2', QPA General Model wheat Module2)	Numbers of industrial enterprises in each NUTS2 giving estimate of proportion of industrial use of wheat in each NUTS of each MS.	Actual data used. No estimate of potential variation.
IndLoss%	Grain losses during industrial use/en route to industrial use	Proportion	Appendix D Spillage of wheat grain and mortality of *L. bonariensis* after arrival at destination	Losses expected to be slightly higher than those at port due to greater handing during these processes, 0.5% used as mean and most likely value. Same values used for all months and MS.	Range unknown but assumed similar to variability to port, 0.25 to 0.75% assumed
Liv%	Annual Livestock Units by NUTS2 region	Numbers, 2009 - 2013	Eurostat national livestock numbers data	Most recent data available as accessed from Eurostat. MISSING VALUES: Data for Germany and Hungary are	Variance from year to year expected to be low at least in short term

				missing and an even distribution across NUTS2 regions within these countries was assumed	
LossGPre %	Percentage going to farm which is lost as whole grain prior to consumption	Proportion	Spillage and loss during the livestock feeding is expected to be significant but no estimate was available. The variability is also expected to be quite high.	Value unknown, 3% used. Same values used for all months and MS.	Range unknown, 2 to 4% used
LossGUn %	Percentage going to farm which is lost as whole grain unaffected by alimentary processes (Undigested)	Proportion	Estimates see Table 3.1.03 and table footnote[#]	0.25% used as mid-point between none and maximum estimate. Same values used for all months and MS.	Range unknown but high variability expected, 0 to 0.5% used
LossFPre %	Percentage going to farm which is lost as feed prior to consumption	Proportion	Spillage and loss during the livestock feeding is expected to be significant but no estimate was available. The variability is also expected to be quite high.	Value unknown, 3% used. Same values used for all months and MS.	Range unknown, 2 to 4% used
LossFUn%	Percentage going to farm which is lost as feed unaffected by alimentary processes (Undigested)	Proportion	Zero assumed as feed pellets easily digested	Zero. Same values used for all months and MS.	Not applicable
Pop%	Annual Population data by NUTS2 (proportion in each NUTS2 region)	Numbers, 2009 - 2013	Eurostat national human population data	Most recent data available as accessed from Eurostat	Variance from year to year expected to be low at least in short term
ConLoss%	Grain product losses from human consumption/en-route consumption	Proportion	Discarded food from consumption is expected to occur but no estimate was	Value unknown, 3% used. Same values used for all months and MS.	Range unknown, 2 to 4% used

			available. The variability is also expected to be quite high.		
Host%	Commodity Area by NUTS2	Area occupied by vulnerable host (proportion of NUTS2 region)	Eurostat data on areas occupied by crop commodities	Data on areas occupied by vulnerable crop expressed as percentage of total area of NUTS2 region	Variance from year to year expected to be low at least in short term
Area	NUTS2 Area	Area of NUT2 Region (km^2)	Eurostat data on areas of NUTS2 regions	As accessed from Eurostat	No variance
Foot%	Pest 'footprint': the area that the pest can reach in period they can survive after release from the imported commodity	Area of footprint calculated from pest mobility (proportion of NUTS2 region)	A proportion of adults (especially those gravid) fly although most will disperse by walking (assume 500m) but that some adults can fly (max = 5km) which seems reasonable based on what is written in NZ literature, and general knowledge about small weevils (Appendix D)	0.5km used. Same values used for all months (with suitable conditions) and MS.	0 – 5km used
SurPL%	Pest survival in grain lost at port	proportion	A large proportion of undetected *L. bonariensis* would survive storage and transport. Appendix D[#]	97.5%. Same values used for all months and MS.	Range unknown but variability expect to be not too great, 96.2% to 98.3% used
SurIn%	Pest survival in grain lost at or en route to industrial uses	proportion	A large proportion of undetected *L. bonariensis* would survive storage and transport.	97.5%. Same values used for all months and MS.	Range unknown but variability expect to be not too great, 96.2% to 98.3%

			Appendix D#		used
SurML%	Pest survival in grain lost at Mill/en route to mill	proportion	A large proportion of undetected *L. bonariensis* would survive storage and transport. Appendix D#	97.5%. Same values used for all months and MS.	Range unknown but variability expect to be not too great, 96.2% to 98.3% used
SurGP%	Pest survival in grain lost at farm prior to feeding	proportion	A large proportion of undetected *L. bonariensis* would survive storage and transport. Appendix D#	97.5%. Same values used for all months and MS.	Range unknown but variability expect to be not too great, 96.2% to 98.3% used
SurGU%	Pest survival in grain undigested by livestock	proportion	Insect pest not expected to survive digestive system	Zero. Same values used for all months and MS.	Not applicable
SurFP%	Pest survival in feed lost at farm prior to feeding	proportion	Insect pest not expected to survive grain processing to feed	Zero. Same values used for all months and MS.	Not applicable
SurFU%	Pest survival in feed undigested by livestock	proportion	Insect pest not expected to survive grain processing to feed or digestive system	Zero. Same values used for all months and MS.	Not applicable
SurHu%	Pest survival in grain products lost at or en route to consumer	proportion	Insect pest not expected to survive in the processing of grain into products for human consumption	Zero. Same values used for all months and MS.	Not applicable
Phen%	Proportion of host production where transfer possible	Proportion	Months in which crop vulnerable to pest taken from temperature thresholds for pest activity and from crop phenologies in northern, central & southern Europe (Appendix D;	Relative cycle of phenological suitability based on timing of crop cycle and requirements of organism; with fully suitable (Phen% = 100%) and unsuitable (Phen% = 0) periods and a progressive	Range unknown: +/- 20% range of variation was assumed in the transition months between suitable and unsuitable periods

			Table 3.1.03). Vulnerable periods: April to September (northern Europe), March to August (central) and November to July (southern)	change (0<Phen%<100 %) from one to the other. Phenological suitability estimated separately for southern, central and northern zones of the EU.	

#Details of Empirical background where indicated in the table

FeedG% Total EU supply of wheat from 2010 to 2014 (Appendix D,) has remained relatively constant at around 154 million tonnes with average import levels of around 5 million tonnes (3.34%). Of this supply approximately equal amounts were used for human consumption (36.3%) and animal feed (31.6%) with the remainder used for seed (3.4%) and feedstock for industrial purposes (6.8%). Use of wheat for bioethanol production accounted for around 41% of the total industrial usage.

LossGUn% Losses of grain as undigested following alimentary processes estimated at up to 0.5% http://www.omafra.gov.on.ca/english/crops/organic/news/2012/2012-10a2.htm, http://www.nutrecocanada.com/docs/shur-gain---beef/finishing-cattle-on-whole-corn.pdf,http://extension.psu.edu/animals/dairy/nutrition/nutrition-and-feeding/troubleshooting-guides/using-manure-evaluation-to-enhance-dairy-cattle-nutrition

SurvPL% A conservative estimate would be to assume grain is in storage at the port of origin for 2-4 weeks and the receiving port 4-8 weeks. Assuming that the shipping time was ~ 5-6 weeks then total storage time would be 11 – 18 weeks. Reported figures for survival of adult *L. bonariensis* range from 62-179 days (~9-26 weeks) suggesting that a large proportion of undetected *L. bonariensis* would survive storage and transport. Conclusion: A conservative estimate is that infestation rates would diminish after 11-18 weeks storage provided egg laying by females did not occur.

3.3. Consignment model parameters

3.3.1. Parameter Entry Template

Parameter input is managed using a parameter entry template which provides a single sheet for all inputs required for the model. The values in the parameter entry template are linked to all the trade chain model sheets, as appropriate. All input variable distributions in the models are specified in this one template. The template is laid out in a series of similar blocks, one for each trade chain (Table 3.3.01). For consistency of layout, all blocks contain the full set of trade chain stages (column headings) and any stages that do not apply to a particular trade chain are shaded grey.

Some parameter values are applicable to more than one trade chain, and to avoid duplication in parameter entry where applicable, values are copied to a corresponding location in other blocks of the template. Only those cells in the template which are shaded pale blue (Fig. 3.2.01) need to be completed.

Consideration has been given to a parameterisation of model variables in order to make them as clear and accessible as possible. All distributions in the model are defined by three parameters: a minimum value, a most likely value (=mode) and maximum value. The @Risk software provides such a parameterisation for the PERT distribution, a generalisation of the Beta distribution, which offers the flexibility in distribution shape (left-skewed, right skewed or Normal-like), and variance, required to reflect the variety of model variables that need to be described.

The sources of information about model variables are given in Sections 3.1. Detailed justifications of the specific values used for each case study are given in Appendices 1 to 4. Model parameters, units, values and variance are summarized for the four case studies in Tables 3.3.02 to 3.3.05.

3.3.2. Selection of parameters to describe model variables

In order to complete the parameter template, minimum, most likely and maximum values of all variables were estimated from the information gathered for the case study pathways, for apple, plum, oranges and wheat (Tables 3.3.02, 3.3.03, 3.3.04 and 3.3.05, respectively). These tables are derived from Sections 3.1 to 3.3 and Appendices 1 to 4.

Table 3.3.01: The data input template for the consignment models for fruit (with parameters shown for the apple - *Cydia prunivora case study*)

All variables are described by Pert distributions defined by the mimimum, most likely (or modal), and maximum values of the distrubtion

Trade chain 1	on arrival			at Airport or harbour			in Transport to wholesale			at wholesale and storage			in Transport to processor			at Processor			in Transport to retail			at Retail			in Transport to consumer			at Consumer		
	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max
Days commodity in stage				0.1	1.25	7													0.2	0.5	3	0	1.5	7	0.005	0.02	0.04	1	6	21
Days in stage before loss				0.1	1.25	7													0.2	0.5	3	1	6	7	0.005	0.02	0.04	1	16	21
Proportion commodity retained during stage				0.98	0.99	1													1	1	1	0.964	0.97	0.976	1	1	1	0.57	0.64	0.71
Daily pest mortality rate in commodity				0.056	0.072	0.108													0.056	0.072	0.108	0.056	0.072	0.108	0.028	0.036	0.054	0.028	0.036	0.054
Daily pest mortality rate in waste etc				0.056	0.072	0.108													0.056	0.072	0.108	0.056	0.072	0.108	0.028	0.036	0.054	0.028	0.036	0.054
Consignment volume 100s kgs	1	5	290																											
Proportion of consignment units infested	0	0	3E-05																											

Trade chain 2	on arrival			at Airport or harbour			in Transport to wholesale			at wholesale and storage			in Transport to processor			at Processor			in Transport to retail			at Retail			in Transport to consumer			at Consumer		
	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max
Days commodity in stage				0.1	1.25	7	0.2	0.5	3	0.2	3	14							0.2	0.5	3	0	1.5	7	0.005	0.02	0.04	1	6	21
Days in stage before loss				0.1	1.25	7	0.2	0.5	3	0.2	3	14							0.2	0.5	3	1	6	7	0.005	0.02	0.04	1	16	21
Proportion commodity retained during stage				0.98	0.99	1	1	1	1	0.98	0.99	1							1	1	1	0.964	0.97	0.976	1	1	1	0.57	0.64	0.71
Daily pest mortality rate in commodity				0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108							0.056	0.072	0.108	0.056	0.072	0.108	0.028	0.036	0.054	0.028	0.036	0.054
Daily pest mortality rate in waste etc				0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108							0.056	0.072	0.108	0.056	0.072	0.108	0.028	0.036	0.054	0.028	0.036	0.054
Consignment volume 100s kgs	1	5	290																											
Proportion of consignment units infested	0	0	3E-05																											

Trade chain 3	on arrival			at Airport or harbour			in Transport to wholesale			at wholesale and storage			in Transport to processor			at Processor			in Transport to retail			at Retail			in Transport to consumer			at Consumer		
	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max
Days commodity in stage				0.1	1.25	7	0.2	0.5	3	0.2	3	14	0.2	0.5	3	1	3	7	0.2	0.5	3	0	1	3	0.005	0.02	0.04	0.2	1	3
Days in stage before loss				0.1	1.25	7	0.2	0.5	3	0.2	3	14	0.2	0.5	3	1	3	7	0.2	0.5	3	1	2.5	3	0.005	0.02	0.04	0.2	2.5	3
Proportion commodity retained during stage				0.98	0.99	1	1	1	1	0.98	0.99	1	1	1	1	0.6	0.7	0.8	1	1	1	0.964	0.97	0.976	1	1	1	0.964	0.97	0.976
Daily pest mortality rate in commodity				0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108	0.99	0.995	1	0.056	0.072	0.108	0.96	0.98	1	0.96	0.98	1	0.96	0.98	1
Daily pest mortality rate in waste etc				0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108	0.056	0.072	0.108	0.96	0.98	1	0.056	0.072	0.108	0.96	0.98	1	0.96	0.98	1	0.96	0.98	1
Consignment volume 100s kgs	1	5	290																											
Proportion of consignment units infested	0	0	3E-05																											

Trade chain 4	on arrival			at Airport or harbour			in Transport to wholesale			at wholesale and storage			in Transport to processor			at Processor			in Transport to retail			at Retail			in Transport to consumer			at Consumer		
	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max	Min	Most likely	Max
Days commodity in stage				0.1	1.25	7							0.2	0.5	3	1	3	7	0.2	0.5	3	0	1	3	0.005	0.02	0.04	0.2	1	3
Days in stage before loss				0.1	1.25	7							0.2	0.5	3	1	3	7	0.2	0.5	3	1	2.5	3	0.005	0.02	0.04	0.2	2.5	3
Proportion commodity retained during stage				0.98	0.99	1							1	1	1	0.6	0.7	0.8	1	1	1	0.964	0.97	0.976	1	1	1	0.964	0.97	0.976
Daily pest mortality rate in commodity				0.056	0.072	0.108							0.056	0.072	0.108	0.99	0.995	1	0.056	0.072	0.108	0.96	0.98	1	0.96	0.98	1	0.96	0.98	1
Daily pest mortality rate in waste etc				0.056	0.072	0.108							0.056	0.072	0.108	0.96	0.98	1	0.056	0.072	0.108	0.96	0.98	1	0.96	0.98	1	0.96	0.98	1
Consignment volume 100s kgs	1	5	290																											
Proportion of consignment units infested	0	0	3E-05																											

Not relevant for that trade chain (grey)   Input cells (light blue)

Table 3.3.02: Parameter values to specify distributions for model variables, data sources and comments on basis of parameter estimates. Parameterisation for import of sweet oranges potentially infested with Asiatic citrus canker, *Xanthomonas citri citri* (ex Hasse 1915) Gabriel et al 1989, from countries where this pest occurs. Grey-shading indicates values judged reasonable but where evidence does not allow a precise quantification

Variable	Stage	Parameters for distributions			Source (A-A refers to Appendix A, S to section)	Comments
		Min	Most likely	Max		
Consignment volume 100 kgs	Arrival	1	200	290	A-A	Most likely value taken as 20 tonnes, and minimum as 100 Kg
Proportion of consignment units infested	Arrival	0	0.000007	0.00002	A-A S 2-6	Calculated from farm gate infestation combined with in-shipment survival estimates. Equates to an aaverage of 0.0008 from US, Japan, S. Korea & S. America
Proportion of consignment units infested	Arrival	0	0.00003	0.00013	A-A S 2-6, 9-10	Calculated from farm gate infestation combined with in-shipment survival estimates. Equates to an aaverage of 0.0042 for other countries than those above
Days commodity in stage	Airport /harbour	0.1	1.25	7		Range from direct throughput to 1 week?
Days in stage before loss	Airport /harbour	0.1	1.25	7		Range from direct throughput to 1 week?
Proportion commodity retained during stage	Airport /harbour	1	1	1		Zero until graded
Daily pest mortality rate in commodity	Airport /harbour	0.025	0.05	0.1	A-A S 6, 9-10	Survival good on host tissue (Appendix C, Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in waste etc	Airport /harbour	0.025	0.05	0.1		
Days commodity in stage	In transport from port	0.2	0.5	3	A-A S 11	Mostly within importing country, small minority transhipped
Days in stage before loss	In transport from port	0.2	0.5	3		
Proportion commodity retained during stage	In transport from port	1	1	1		Zero until graded
Daily pest mortality rate in commodity	In transport from port	0.025	0.05	0.1	A-A S 11-12	Survival good on host tissue (Appendix C, Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in	In transport from	0.025	0.05	0.1		

waste etc	port					
Days commodity in stage	At wholesale/storage	0.2	3	14		Range from direct throughput to 2 weeks? Not usual to store long term in importing country
Days in stage before loss	At wholesale/storage	0.2	3	14		
Proportion commodity retained during stage	At wholesale/storage	0.964	.97	0.976	A-A S 17	Loss of 0.03 +/- 20% used. 3% of fruit rejected at post-import grading
Daily pest mortality rate in commodity	At wholesale/storage	0.025	0.05	0.1	A-A S 6-7	Survival good on host tissue (Appendix C Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in waste etc	At wholesale/storage	0.025	0.05	0.1		
Days commodity in stage	At processor	1	3	7		Processed within 1 week?
Days in stage before loss	At processor	1	3	7		Processed within 1 week?
Proportion commodity retained during stage	At processor	0.964	.97	0.976	A-A, S 10	Loss of 0.03 +/- 20% used. 3% of fruit rejected at post-import grading
Daily pest mortality rate in commodity	At processor	1	1	1	A-A S 10	Processes kill pest
Daily pest mortality rate in waste etc	At processor	0.1	0.8	1	A-A S 10	Most processes kill pest but degree of survival assumed in sun-drying peel
Days commodity in stage	At retail (fresh fruit)	0	1.5	7		Expected to sell with a day or two, up to 1 week?
Days in stage before loss	At retail (fresh fruit)	1	6	7		Losses expected to be towards the end of the retail period
Proportion commodity retained during stage	At retail (fresh fruit)	.975	0.9775	.98	A-A S 11, 17	2 – 2.5% losses at retail
Daily pest mortality rate in commodity	At retail (fresh fruit)	0.025	0.05	0.1	A-A S 6	Survival good on host tissue (Appendix C, Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in waste etc	At retail (fresh fruit)	0.025	0.05	0.1		
Days commodity in stage	At retail (processed fruit)	0	1	3		Short shelf life of processed fresh fruit, up to 3 days?
Days in stage before loss	At retail (processed fruit)	1	2.5	3		Losses increase towards 'sell-by' date
Proportion commodity retained during stage	At retail (processed fruit)	.975	0.9775	.98	A-A S 11, 17	2 – 2.5% losses at retail

Daily pest mortality rate in commodity	At retail (processed fruit)	1	1	1	A-A S 10	Processes kill pest
Daily pest mortality rate in waste etc	At retail (processed fruit)	1	1	1		
Days commodity in stage	In transp. to consumer	0.005	0.02	0.04		A few minute to an hour from the shop likely?
Days in stage before loss	In transp. to consumer	0.005	0.02	0.04		
Proportion commodity retained during stage	In transp. to consumer	1	1	1		No loss opportunity
Daily pest mortality rate in commodity	In transp. to cons. (fresh)	0.025	0.05	0.1	A-A S 6	Survival good on host tissue (Appendix C, Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in waste etc	In transp. to cons. (fresh)	0.025	0.05	0.1		
Daily pest mortality rate in commodity	In transp. to cons. (proc.)	1	1	1	A-A S 10-11	Processes kill pest
Daily pest mortality rate in waste etc	In transp. to cons. (proc.)	1	1	1		
Days commodity in stage	At consumer (fresh)	1	6	21		Oranges can last for up to 3 weeks at consumer
Days in stage before loss	At consumer (fresh)	1	16	21		Losses increasing towards end of fruit life with consumer
Proportion commodity retained during stage	At consumer (fresh)	.4	.5	.6	A-A	Peel about 50%, Assumed +/- 20%.
Daily pest mortality rate in commodity	At consumer (fresh)	0.025	0.05	0.1	A-A S 6	Survival good on host tissue (Appendix C, Section 3.1) Daily mortality rates estimated quite low
Daily pest mortality rate in waste etc	At consumer (fresh)	0.025	0.05	0.1		
Days commodity in stage	At consumer (processed)	0.2	1	3		Expected to be useable for up to 3 days?
Days in stage before loss	At consumer (processed)	0.2	2.5	3		Losses expected towards end of period
Proportion commodity retained during stage	At consumer (processed)	.975	0.9775	.98	A-A S 10, 17	2 – 2.5% losses assumed as in retail

Daily pest mortality rate in commodity	At consumer (processed)	1	1	1	A-A S 10	Processes kill pest
Daily pest mortality rate in waste etc	At consumer (processed)	1	1	1	A-A S 10	Processes kill pest

Notes: Days commodity in stage – before moving to next stage; Proportion commodity retained during stage - that not retained goes to loss, waste or by-product depending on the commodity and stage; transport from port - to wholesale, storage, retail and processing; At retail (processed fruit) – concerns processed fruit in which some pests have possibility to survive, e.g. in peeled/cropped fruit for fruit salad. Template completed with possible values in pale grey type to be changed to black type when evidenced.

Table 3.3.03: Parameter values to specify distributions for model variables, data sources and comments on basis of parameter estimates. Parameterisation for import of Dessert apples from USA and Canada having potential infestation with the pest, lesser apple worm, *Cydia prunivora*. Grey-shading indicates values judged reasonable but where evidence does not allow a precise quantification

Variable	Stage	Parameters for distributions			Source (A-B refers to Appendix B; S to section)	Comments
		Min	Most likely	Max		
Consignment volume 100 kgs	Arrival	1	5	290	A-B	Most likely value taken as 0.5 tonnes, and minimum as 100 Kg. Maximum taken as container maximum
Proportion of consignment units infested	Arrival	0	0	0.000034	A-B S 5, 6 and 9	Calculated from farm gate infestation combined with in-shipment survival estimates
Days commodity in stage	Airport /harbour	0.1	1.25	7		Range from direct throughput to 1 week?
Days in stage before loss	Airport /harbour	0.1	1.25	7		Range from direct throughput to 1 week?
Proportion commodity retained during stage	Airport /harbour	0.98	0.99	1		Loss from damage during handling?
Daily pest mortality rate in commodity	Airport /harbour	0.056	0.072	0.108	A-B, S9	Mostly likely calculated from 0.05 survival after 40 days, min 0.01 survival and max 0.1, after 40 days
Daily pest mortality rate in waste etc	Airport /harbour	0.056	0.072	0.108		
Days commodity in stage	In transport from port	0.2	0.5	3	A-B, S 18	Mostly within importing country, small minority transhipped
Days in stage before loss	In transport from port	0.2	0.5	3		
Proportion commodity retained during stage	In transport from port	1	1	1		No loss opportunity
Daily pest mortality rate in commodity	In transport from port	0.056	0.072	0.108	A-B, S 9	
Daily pest mortality rate in waste etc	In transport from port	0.056	0.072	0.108		

Days commodity in stage	At wholesale/storage	0.2	3	14		Range from direct throughput to 2 weeks? Not usual to store long term in importing country
Days in stage before loss	At wholesale/storage	0.2	3	14		
Proportion commodity retained during stage	At wholesale/storage	0.98	0.99	1		Loss from damage during handling?
Daily pest mortality rate in commodity	At wholesale/storage	0.056	0.072	0.108	A-B, S 9	
Daily pest mortality rate in waste etc	At wholesale/storage	0.056	0.072	0.108		
Days commodity in stage	At processor	1	3	7		Processed within 1 week?
Days in stage before loss	At processor	1	3	7		Processed within 1 week?
Proportion commodity retained during stage	At processor	0.6	0.7	0.8		After peel, core, pulp, spoilt fruit (similar to consumer)
Daily pest mortality rate in commodity	At processor	0.99	0.995	1	A-B, S26	Near 100% (except perhaps fruit salad?)
Daily pest mortality rate in waste etc	At processor	0.96	0.98	1	A-B, S26	If 10% is composted & 20% survives composting
Days commodity in stage	At retail (fresh fruit)	0	1.5	7		Expected to sell with a day or two, up to 1 week?
Days in stage before loss	At retail (fresh fruit)	1	6	7		Losses expected to be towards the end of the retail period
Proportion commodity retained during stage	At retail (fresh fruit)	0.964	0.97	0.976	Table 3.1.03	0.03 +/- 20% used. 3% of fruit in retail is rejected as waste whole.
Daily pest mortality rate in commodity	At retail (fresh fruit)	0.056	0.072	0.108	A-B, S 9	
Daily pest mortality rate in waste etc	At retail (fresh fruit)	0.056	0.072	0.108		
Days commodity in stage	At retail (processed fruit)	0	1	3		Short shelf life of processed fresh fruit, up to 3 days?
Days in stage before loss	At retail (processed fruit)	1	2.5	3		Losses increase towards 'sell-by' date
Proportion commodity retained	At retail (processed	0.964	0.97	0.976	Table	0.03 +/- 20% used. 3% of fruit in retail is

during stage	fruit)				3.1.03	rejected as waste whole
Daily pest mortality rate in commodity	At retail (processed fruit)	0.96	0.98	1	A-B, S26	Expected high in chopped fruit
Daily pest mortality rate in waste etc	At retail (processed fruit)	0.96	0.98	1		
Days commodity in stage	In transp. to consumer	0.005	0.02	0.04		A few minute to an hour from the shop likely?
Days in stage before loss	In transp. to consumer	0.005	0.02	0.04		
Proportion commodity retained during stage	In transp. to consumer	1	1	1		No loss opportunity
Daily pest mortality rate in commodity	In transp. to cons. (fresh)	0.028	0.036	0.054		Mortality in indoor ambient conditions guessed to be half that in controlled storage conditions
Daily pest mortality rate in waste etc	In transp. to cons. (fresh)	0.028	0.036	0.054		
Daily pest mortality rate in commodity	In transp. to cons. (proc.)	0.96	0.98	1	A-B, S24	Expected high in chopped fruit
Daily pest mortality rate in waste etc	In transp. to cons. (proc.)	0.96	0.98	1		
Days commodity in stage	At consumer (fresh)	1	6	21		Apples can last for up to 3 weeks at consumer
Days in stage before loss	At consumer (fresh)	1	16	21		Losses increasing towards end of fruit life with consumer
Proportion commodity retained during stage	At consumer (fresh)	0.57	0.64	0.71	Table 3.1.03	20%, Peel and core of fruit + 20% of fruit is rejected as waste whole +/- 20%
Daily pest mortality rate in commodity	At consumer (fresh)	0.028	0.036	0.054		Mortality in indoor ambient conditions guessed to be half that in controlled storage conditions. Most do not refrigerate
Daily pest mortality rate in waste etc	At consumer (fresh)	0.028	0.036	0.054		
Days commodity in stage	At consumer (processed)	0.2	1	3		Expected to be useable for up to 3 days?
Days in stage before loss	At consumer (processed)	0.2	2.5	3		Losses expected towards end of period

Proportion commodity retained during stage	At consumer (processed)	0.964	0.97	0.976	Table 3.1.03	0.03 +/- 20% used. 3% of fruit is rejected
Daily pest mortality rate in commodity	At consumer (processed)	0.96	0.98	1	A-B, S24-26	*Expected high in chopped fruit*
Daily pest mortality rate in waste etc	At consumer (processed)	0.96	0.98	1		

Notes: Days commodity in stage – before moving to next stage; Proportion commodity retained during stage - that not retained goes to loss, waste or by-product depending on the commodity and stage; transport from port - to wholesale, storage, retail and processing; At retail (processed fruit) – concerns processed fruit in which some pests have possibility to survive, e.g. in peeled/cropped fruit for fruit salad. Template completed with possible values in pale grey type to be changed to black type when evidenced.

Table 3.3.04: Parameter values to specify distributions for model variables, data sources and comments on basis of parameter estimates. Parameterisation for import of Plums from USA and Canada having potential infestation with the pest, Plum weevil *Conotrachelus nenuphar* (Herbst). Grey-shading indicates values judged reasonable but where evidence does not allow a precise quantification

Variable	Stage	Parameters for distributions			Source (A-C refers to Appendix C ; S to section)	Comments
		Min	Most likely	Max		
Consignment volume 100 kgs	Arrival	1	5	290		Assumed similar to apple, values for stone fruits
Proportion of consignment units infested	Arrival	0	0	0.001	A-C, S 7 and 8	Calculated from farm gate infestation combined with in-shipment survival estimates
Days commodity in stage	Airport /harbour	0.1	1.25	3	A-C, S 8	Range from direct throughput to 3 days ?
Days in stage before loss	Airport /harbour	0.1	1.25	3		Range from direct throughput to 3 days?
Proportion commodity retained during stage	Airport /harbour	0.98	0.99	1		Loss from damage during handling?
Daily pest mortality rate in commodity	Airport /harbour	0.074	0.11	0.14	A-C, S 8	Mostly likely calculated from 'near 100%' (99.9% used) mortality after 60 days. Range +/- order of magnitude
Daily pest mortality rate in waste etc	Airport /harbour	0.074	0.11	0.14		
Days commodity in stage	In transport from port	0.2	0.5	3		Mostly within importing country, small minority transhipped, MacLeod Pg. 17
Days in stage before loss	In transport from port	0.2	0.5	3		Mostly within importing country, small minority transhipped, MacLeod Pg. 17
Proportion commodity retained during stage	In transport from port	1	1	1		No loss opportunity
Daily pest mortality rate in commodity	In transport from port	0.074	0.11	0.14	A-C, S 8	
Daily pest mortality rate in waste etc	In transport from port	0.074	0.11	0.14		
Days commodity in stage	At wholesale/storage	0.2	3	7	A-C, S 89	Range from direct throughput to 1 weeks? Plum storage life shorter than apples

Days in stage before loss	At wholesale/storage	0.2	3	7	A-C, S 8	
Proportion commodity retained during stage	At wholesale/storage	0.98	0.99	1		Loss from damage during handling?
Daily pest mortality rate in commodity	At wholesale/storage	0.074	0.11	0.14	A-C, S 8	
Daily pest mortality rate in waste etc	At wholesale/storage	0.074	0.11	0.14		
Days commodity in stage	At processor	1	2	3	A-C, S 8	Processed within 3 days?
Days in stage before loss	At processor	1	2	3		Processed within 3 days?
Proportion commodity retained during stage	At processor	0.964	0.97	0.976	Table 3.1.03	3% of fruit is rejected as waste whole +/- 20%
Daily pest mortality rate in commodity	At processor	0.99	0.995	1	A-C, S23	Near 100% (except perhaps fruit salad?)
Daily pest mortality rate in waste etc	At processor	0.96	0.98	1	A-C, S 23	If 10% is composted & 20% survives composting
Days commodity in stage	At retail (fresh fruit)	0	1.5	5	A-C, S 8	Expected to sell with a day or two, up to 1 week?
Days in stage before loss	At retail (fresh fruit)	1	5	6		Losses expected to be towards the end of the retail period
Proportion commodity retained during stage	At retail (fresh fruit)	0.964	0.97	0.976	Table 3.1.03	0.03 +/- 20% used. 3% of fruit in retail is rejected as waste whole
Daily pest mortality rate in commodity	At retail (fresh fruit)	0.074	0.11	0.14	A-C, S 8	
Daily pest mortality rate in waste etc	At retail (fresh fruit)	0.074	0.11	0.14		
Days commodity in stage	At retail (processed fruit)	0	1	3		Short shelf life of processed fresh fruit, up to 3 days?
Days in stage before loss	At retail (processed fruit)	1	2.5	3		Losses increase towards 'sell-by' date
Proportion commodity retained during stage	At retail (processed fruit)	0.964	0.97	0.976	Table 3.1.03	0.03 +/- 20% used. 3% of fruit in retail is rejected as waste whole
Daily pest mortality rate in commodity	At retail (processed fruit)	0.96	0.98	1	A-C, S 23	Expected high in chopped fruit
Daily pest mortality rate in	At retail (processed	0.96	0.98	1		

waste etc	fruit)					
Days commodity in stage	In transp. to consumer	0.005	0.02	0.04		A few minute to an hour from the shop likely?
Days in stage before loss	In transp. to consumer	0.005	0.02	0.04		
Proportion commodity retained during stage	In transp. to consumer	1	1	1		No loss opportunity
Daily pest mortality rate in commodity	In transp. to cons. (fresh)	0.037	0.055	0.07	A-C, S 8	Mortality in indoor ambient conditions guessed to be half that in controlled storage conditions
Daily pest mortality rate in waste etc	In transp. to cons. (fresh)	0.037	0.055	0.07		
Daily pest mortality rate in commodity	In transp. to cons. (proc.)	0.96	0.98	1	A-C, S 23	Expected high in chopped fruit
Daily pest mortality rate in waste etc	In transp. to cons. (proc.)	0.96	0.98	1		
Days commodity in stage	At consumer (fresh)	1	6	21		Plums can last for up to 3 weeks at consumer
Days in stage before loss	At consumer (fresh)	1	16	21		Losses increasing towards end of fruit life with consumer
Proportion commodity retained during stage	At consumer (fresh)	0.964	0.97	0.976	Table 3.1.03	3% of fruit is rejected as waste whole. +/- 20%
Daily pest mortality rate in commodity	At consumer (fresh)	0.037	0.055	0.07	A-C, S 8	Mortality in indoor ambient conditions guessed to be half that in controlled storage conditions. Most do not refrigerate
Daily pest mortality rate in waste etc	At consumer (fresh)	0.037	0.055	0.07		
Days commodity in stage	At consumer (processed)	0.2	1	3		Expected to be useable for up to 3 days?
Days in stage before loss	At consumer (processed)	0.2	2.5	3		Losses expected towards end of period
Proportion commodity retained during stage	At consumer (processed)	0.964	0.97	0.976	Table 3.1.03	0.03 +/- 20% used. 3% of fruit is rejected.
Daily pest mortality rate in commodity	At consumer (processed)	0.96	0.98	1	A-C, S 23	Expected high in chopped fruit
Daily pest mortality rate in waste etc	At consumer (processed)	0.96	0.98	1		

Notes: Days commodity in stage – before moving to next stage; Proportion commodity retained during stage - that not retained goes to loss, waste or by-product depending on the commodity and stage; transport from port - to wholesale, storage, retail and processing; At retail (processed fruit) – concerns processed fruit in which some pests have possibility to survive, e.g. in peeled/cropped fruit for fruit salad. Template completed with possible values in pale grey type to be changed to black type when evidenced.

Table 3.3.05: Parameter values to specify distributions for model variables, data sources and comments on basis of parameter estimates. Parameterisation for imports of wheat from Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand having potential infestation with the pest, Argentine stem weevil, *Listronotus bonariensis* (Kuschel) Grey-shading indicates values judged reasonable but where evidence does not allow a precise quantification. Grey-shading indicates values judged reasonable but where evidence does not allow a precise quantification

Variable	**Stage**	**Parameters for distributions**			**Source** (A-D refers to Appendix D; S to section)	**Comments**
		Min	**Most likely**	**Max**		
Consignment volume 100 kgs	Arrival	50	75	400	A-D	Upper limit not known
Proportion of consignment units infested	Arrival	0	0	0.0001	A-D	Taking into account infestation at export, high survival in transit and low detection rate at entry
Days commodity in stage	Harbour	2	3	4	A-D, S 9	Usual unloading time range
Days in stage before loss	Harbour	2	3	4		
Proportion commodity retained during stage	Harbour	0.994	0.996	0.998	A-D, S 9	Loss during handling
Daily pest mortality rate in commodity	Harbour	0.017	0.025	0.038	A-D, S9	Proportion survival of 0.001, 0.01, 0.05 after 179 days
Daily pest mortality rate in waste etc	Harbour	0.017	0.025	0.038		
Days commodity in stage	In transport from port	2	3	5	A-D, S9	
Days in stage before loss	In transport from port	2	3	5		
Proportion commodity retained during stage	In transport from port	0.999	0.9992	0.9994	A-D, S 9	
Daily pest mortality rate in commodity	In transport from port	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	In transport from port	0.017	0.025	0.038		
Days commodity in stage	At wholesale/storage	0	42	200	A-D, S 9	Storage may be at the port or elsewhere
Days in stage before loss	At wholesale/storage	0	42	200	A-D, S 9	

Proportion commodity retained during stage	At wholesale/storage	0.994	0.996	0.998	A-D, S 9	Loss during handling
Daily pest mortality rate in commodity	At wholesale/storage	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	At wholesale/storage	0.017	0.025	0.038		
Days commodity in stage	At mill	1	7	28		Estimated – up to 4 weeks?
Days in stage before loss	At mill	1	7	28		
Proportion commodity retained during stage	At mill	0.993	0.995	0.997	A-D, S 9	
Daily pest mortality rate in commodity	At mill (grain feed for livestock)	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	At mill (grain feed for livestock)	0.017	0.025	0.038		
Daily pest mortality rate in commodity	At mill (by-product for feed manufacture)	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	At mill (by-product for feed manufacture)	1	1	1		
Daily pest mortality rate in commodity	At mill (products for food processor)	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	At mill (products for food processor)	1	1	1		
Daily pest mortality rate in commodity	At mill (products for retail)	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	At mill (products for retail)	1	1	1		
Days commodity in stage	At feed manufacturer	1	7	28		Estimated – up to 4 weeks?
Days in stage before loss	At feed manufacturer	1	7	28		
Proportion commodity retained during stage	At feed manufacturer	0.993	0.995	0.997	A-D, S 9	
Daily pest mortality rate in commodity	At feed manufacturer	1	1	1	A-D, S 9	
Daily pest mortality rate in	At feed manufacturer	1	1	1		

waste etc						
Days commodity in stage	In transport to farm	0.1	0.2	1		Estimated - up to 1 day may be reasonable?
Days in stage before loss	In transport to farm	0.1	0.2	1		
Proportion commodity retained during stage	In transport to farm	0.999	0.9992	0.9994	A-D, S 9	
Daily pest mortality rate in commodity	In transport to farm	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	In transport to farm	0.017	0.025	0.038		
Days commodity in stage	At farm storage (grain)	1	7	60		Estimated - up to 2 months may be reasonable?
Days in stage before loss	At farm storage (grain)	1	7	60		
Proportion commodity retained during stage	At farm storage (grain)	0.993	0.995	0.997	A-D, S 9	Estimated – but could be higher for on-farm facilities?
Daily pest mortality rate in commodity	At farm storage (grain)	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	At farm storage (grain)	0.017	0.025	0.038		
Days commodity in stage	In transport to livestock (grain)	0	0.01	0.04		
Days in stage before loss	In transport to livestock (grain)	0	0.01	0.04		
Proportion commodity retained during stage	In transport to livestock (grain)	0.999	0.9992	0.9994	A-D, S 9	Estimated - but could be higher for on-farm transport?
Daily pest mortality rate in commodity	In transport to livestock (grain)	0.017	0.025	0.038	A-D, S 9	
Daily pest mortality rate in waste etc	In transport to livestock (grain)	0.017	0.025	0.038		
Days commodity in stage	At livestock (grain)	0	0.2	1		Feed likely to be consumed within one day?
Days in stage before loss	At livestock (grain)	0	0.2	1		
Proportion commodity retained during stage	At livestock (grain)	0.85	0.9	0.95		Estimated - losses likely high at point of feeding
Daily pest mortality rate in commodity	At livestock (grain)	0.017	0.025	0.038	A-D, S 9	

Daily pest mortality rate in waste etc	At livestock (grain)	0.017	0.025	0.038		
Days commodity in stage	At food processor	1	7	28		Estimated – up to 4 weeks?
Days in stage before loss	At food processor	1	7	28		
Proportion commodity retained during stage	At food processor	0.993	0.995	0.997	A-D, S 9	
Daily pest mortality rate in commodity	At food processor	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	At food processor	1	1	1		
Days commodity in stage	At retailer (flour)	1	7	28		Estimated – up to 4 weeks?
Days in stage before loss	At retailer (flour)	1	7	28		
Proportion commodity retained during stage	At retailer (flour)	0.99	0.995	1		
Daily pest mortality rate in commodity	At retailer (flour)	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	At retailer (flour)	1	1	1		
Days commodity in stage	In transport to consumer (flour)	0.01	0.02	0.04		Estimated - up to about an hour
Days in stage before loss	In transport to consumer (flour)	0.01	0.02	0.04		
Proportion commodity retained during stage	In transport to consumer (flour)	0.999	0.9992	0.9994	A-D, S 9	
Daily pest mortality rate in commodity	In transport to consumer (flour)	1	1	1	A-D, S 9	
Daily pest mortality rate in waste etc	In transport to consumer (flour)	1	1	1		
Days commodity in stage	At consumer (flour)	0.05	7	60		Estimated - up to 2 months may be reasonable?
Days in stage before loss	At consumer (flour)	0.05	7	60		
Proportion commodity retained during stage	At consumer (flour)	0.993	0.995	0.997	A-D, S 9	
Daily pest mortality rate in commodity	At consumer (flour)	1	1	1	A-D, S 9	

Daily pest mortality rate in waste etc	At consumer (flour)	1	1	1		

Notes: Days commodity in stage – before moving to next stage; Proportion commodity retained during stage - that not retained goes to loss, waste or by-product depending on the commodity and stage; transport from port - to wholesale, storage, retail and processing; At retail (processed fruit) – concerns processed fruit in which some pests have possibility to survive, e.g. in peeled/cropped fruit for fruit salad. Template completed with possible values in pale grey type to be changed to black type when evidenced.

The Consignment model has 147 parameter values listed in each of the Tables 3.3.02-05. Many of the parameter values are similar or identical for different commodities because these tables include both transport functions and biological functions. Commercial transport functions are common for all perishable fruit commodities, whereas the biological parameters can have quite different values depending on the nature of the commodity or the pest involved. We have compared the values for apples and oranges to compare the similarity of values.

- 72 of the 147 values are the same in the two tables. 54 of the 72 parameter values that are common are for time periods for commodities to be handled. All fresh fruits are perishable commodities that must be handled quickly and the values reflect the rapid throughput in commercial practice for all fruits, and a common storage by consumer. Waste can also be considered to be handled as a common bulk commodity, regardless of fruit type.
- 9 of the other 18 parameter values that are common between apples and oranges are max values of proportions that have an upper limit of 1
- 2 of the other 9 parameter values that are common between apples and oranges are the minimum volume of a consignment (100 kg, an arbitrary low value) and the max value (29 tonnes, the payload capacity of a typical reefer shipping container, whether carrying apples or oranges).
- 6 of the remaining 7 parameter values that are common between apples and oranges are the min, most likely and max proportion retained in transport from port and transport to consumer, all set at 1. There is no opportunity for loss or for measuring loss during these very short transfers by refrigerated truck.
- The 1 remaining common parameter value is the minimum proportion of consignment units infested at shipping, which is zero.

4. Sensitivity Analysis

4.1. Introduction

This section includes the sensitivity analysis of the final models, both for the general and the single consignment approach. It also includes a comparison and discussion of the models, particularly focusing on differences between them and common features among the four groups of edible plant products, uncertainties resulting from sensitive parameters and research needs for data gaps identified.

4.2. General model methods

The sensitivity analysis of the general models addresses:

- Variation in trade from year to year
- Possible infestation rate differences between source countries
- Partitioning of imports between different uses
- The location of processing enterprises

Considering these model components in turn:

1. Trade volume from different source countries. The models were parameterised with monthly trade volumes from the 5 years 2010-2014. Trade volume is a primary determinant of pest entry challenge. It is not constant from year to year. To examine the effects of variation in trade pattern, the trade data for each of the five years was used separately to parameterise the models and the outcomes compared to assess the degree to which year to year fluctuations in trade over this period have led to fluctuations in pest risk.

Table 4.2.01: Trade sensitivity parameters

Model sheet	Models	Parameter name	Sensitivity analysis
A1: Imports by Source Country by Month (Module 1)	All	Vol%	Individual yearly data, or totals (expressed per year) for the sequence of years. (Effects of year to year differences were examined)

2. In the parameterisation of the final model it was possible to estimate a general rate of infestation for the case study pests which has, in each model, been applied to the commodity from the relevant source countries. In the case of the orange model, two groups of source countries were identified for which different infestation rate estimates were obtained. Different potential source countries have different patterns of export to the EU so differences in infestation rates in the commodity from different source countries will result in different risk patterns within the EU. If a particular source country were to have a more severe outbreak of the pest concerned then there may be an increase in pest infestation rate in the commodity from that country. As an indication of the effect this might have, the relative difference in pest infestation rate of the commodity between source countries was varied. In the case studies for the plum and apple models, only two known source countries exist. In the sweet orange model, two clusters of source countries can be identified according to their level of estimated infestation. In the wheat model, two clusters of source countries can be identified according to global region. In each case, sensitivity to the global pattern of infestation was examined by doubling the infestation rate in the particular countries (apple and plum models) or country clusters (orange and wheat models).

Table 4.2.02: Infestation sensitivity parameters

Model sheet	Models	Parameter name	Sensitivity analysis
Input 1: Infestation levels of imports by Country by Month (Module 1)	Apple, Plum	Inf%	Effects of differences in infestation rate between the two source countries were examined in sensitivity analyses
	Orange		Base infestation 0.0008% from US, Japan, S. Korea & S. America and 0.0042% for other countries that are known sources. Effects of the relative differences between the two groups of countries were examined in sensitivity analyses
	Wheat		Effects of the relative differences between the two clusters of countries (South American and Australasian) were examined in sensitivity analysis

By combining the results from different trade patterns and different global infestation patterns, eight scenarios of Module1 were generated for each of the Models. The table below gives the codes used to distinguish the different realisations of the models for Module 1.

Table 4.2.03: Summarising the combinations of trade volume and infestation scenarios investigated. The codes shown identify the sensitivity analysis scenarios, e.g. Av(0) refers to the scenario with average trade data and infestation patterns as parameterised in the final model

Trade Year scenario	Infestation scenario		
	As parameterised in final models	Country/cluster 1* doubled	Country/cluster 2* doubled
2010	2010(0)		
2011	2011(0)		
2012	2012(0)		
2013	2013(0)		
2014	2014(0)		
2010-2014 Average	Av(0)	Av(1)	Av(2)

*Country 1 = Canada, Country 2 = US (Apple and Plum models); Cluster 1 = US, Japan, S. Korea & S. America, Cluster 2 = other countries that are known sources (Orange model); Cluster 1 = South American countries, Cluster 2 = Australasian countries (Wheat model)

3. In the three fruit models, retail and processing uses have different implications for the patterns of risk because of the different distributions of the locations where these uses occur. The sensitivity of the pattern of risk to the proportion of commodity allocated to processing and retail was examined. In the case of the wheat model, parallel considerations apply to the proportions allocated to milling and industrial uses and the influence of this proportion was examined in the wheat model.

Three scenarios were examined:

- all commodity goes to processing (fruit) or mills (wheat);
- all commodity goes to retail (fruit) or other uses (wheat);
- the standard deviation in the quantity going to processing (fruit) or mills (wheat) is doubled, with the mean remaining as estimated.

The first two scenarios were included in order to examine the differences in pattern between the risk associated with retail and processing or between milling and other uses. The third scenario is used to examine the importance of uncertainty in the variability of the estimates used of the quantity of commodity going to processing (fruits) or milling (wheat).

Table 4.2.04: Use-stream proportion sensitivity parameters

Model sheet	Models	Parameter name	Sensitivity analysis
Input 2: Processing percentage by Country (Module 2)	Apple Plum Orange	Proc%	Sensitivity analysis of percentage going to processing, as risks associated with processing use have different geographical distribution compared to retail use. Disaggregation of risk associated with processing and with retail.
Input 3: Mill and Other Uses by Country (Module 2)	Wheat	ToMills%	Sensitivity analysis of percentage going to mills rather than industrial uses, as risks from milling have different geographical distribution compared to feed use. Disaggregation of risk associated with milling and with industrial use.

The location of fruit and vegetable processors of the specific commodities was difficult to establish in most cases so data representing all fruit and vegetable food processing enterprises was used. This aggregated processing-business data is expected to include more businesses that are not specifically relevant than would data relating to a specific commodity, if it were available. To take account of this in the model, the proportion of enterprises in each NUTS2 region of a country is treated as the upper limit with a linear decline in probability of the relevant proportion for a particular commodity being lower than this. The modelled means therefore reflect the number of enterprises and the associated variances reflect the uncertainty about which enterprises deal specifically with the commodity concerned. The lower limit was taken as zero, as in some cases none of the identified processors may process the commodity of interest. The modelled means therefore reflect the proportions of listed enterprises in each NUTS2 region of a country and the associated variances reflect uncertainty about which enterprises deal specifically with the commodity concerned. In the sensitivity analysis, comparison was made between the assumptions above (provided as part of the final models) and an alternative assumption that processors were evenly distributed among NUTS2 regions. This provides a baseline by which to compare the effect of processing enterprise distribution on the results.

Table 4.2.05: Processing location uncertainty sensitivity parameters

Model sheet	Models	Parameter name	Sensitivity analysis
Processing Units by NUTS2 (Module 2)	Apple, Plum, Orange	ProcN%	The effect of uncertainty in processor activity was examined in sensitivity analyses.

Table 4.2.06: Summarising the combinations of import use and processing location scenarios investigated. The codes shown identify the sensitivity analysis scenarios and are also linked to the codes above, e.g. Av(0)Pf refers to a model realisation with average trade data, infestation patterns as parameterised in the final model, all commodity going to processing, and where processing is correlated with distribution of all food and vegetable processors in a country. Av(0)x1f is effectively the base case

Commodity use	Numbers of listed fruit and vegetable processors in each NUTS2 region	
	Processing correlated with distribution of all food and vegetable processors in a country	Processing evenly distributed across NUTS2 regions of a country
All commodity goes to processing (fruit) or mills (wheat)	Pf	Pg
All commodity goes to retail (fruit) or other uses (wheat)	Rf (commodity goes to retail so any processor location is irrelevant)	
The standard deviation in the quantity going to processing (fruit) or mills (wheat) are as parameterised in the final model	x1f	x1g
The standard deviation in the quantity going to processing (fruit) or mills (wheat) is doubled, with the mean remaining as estimated in the final model parameters	x2f	x2g

4.3. Consignment model methods

In the general model, the trade is partitioned between pathways and uses so the outcome is sensitive to how that partitioning takes place. In the consignment model, a consignment is followed down all possible routes separately in order to investigate the implications of each for pest viability and the timeframe for potential pest transfer along each pathway. In all the consignment models estimates of decline in viability over time were obtained (Appendices 1 to 4) but particular value uncertainty exists about the length of time that the commodity spends in some of the stages of the trade chain. Reasonable estimates of the distributions for each stage have been made in the models provided. As with the general models, the consignments models are linear, so a day added at some point in a pathway adds a day to the total pathway duration. The cumulative effect of increased variance at several stages of the pathway is less transparent. Sensitivity analysis was used to examine the effect of higher variance scenarios on total pathway duration and the implications of this for potential pest release was compared with the standard model assumptions.

Table 4.3.01: Consignment model sensitivity parameters

Model sheet	Models	Parameter name	Sensitivity analysis
Parameters (Consignment Model)	All	Days Commodity in stage; Days Commodity in stage before loss, for all stages[1]: on Arrival, at Airport or harbour, in Transport to wholesale, at Wholesale and storage, in Transport to processor, at Processor, in Transport to retail, at Retail, in Transport to consumer, and at Consumer	Sensitivity analysis compares the standard model with high variance scenarios for each model to assess the effects on total pathway duration and the risk of pest release

[1]Stages for fruit models; a corresponding set of stages apply for the wheat model, see results section.

4.4. General model results

4.4.1. Orange model

Sensitivity of infested volume entering Member States

The trade volume entering different states from different source countries varies from year to year. The infested volume entering Member States is the final output from Module 1 and gives the amount of infested material arriving in each Member State. The pattern of infested volume entering Member States was in broad terms reasonably stable over the years 2010 to 2014, with high risk and low risk countries remaining consistently so throughout the period (Table 4.4.01). However, there were some changes in risk, for example, the infested volumes entering the Netherlands has declined by about two thirds over this period.

The different source countries of the pest concerned have different patterns of export to the EU so any differences in infestation rates in the commodity from different source countries are expected to result in different risk patterns within the EU. To gain some understanding of the potential importance of such effects, scenarios were simulated in which infestation rates from selected source countries or groups of countries were increased. Patterns were revealed which reflected the fact that the main sources of EU imports were from Cluster 1 (US, Japan, S. Korea & S. America). Doubling the infestation rate of imports from Cluster 1 countries approximately doubled volumes entering the main importing Member States; in contrast, doubling infestation from the less important importers had little effect (Table 4.4.02). The Cluster 2 countries were those judged to have a risk of higher infestation rates and it is informative that further increase in infestation risk in those countries which were judged to have higher infestation potential did little to increase risk to EU Member States.

Sensitivity of risk of pest contact

The risk of pest contact is the ultimate model output presented in the final step of Module 2. The risk of pest contact is calculated as the product of the volume of the infested material arriving (100 kg) and vulnerable area accessible by the pest (km^2).

The risk of contact was calculated for every NUTS2 region in every month of the year. The results were ranked with the highest risk at the top. The top 50 most risky combinations of NUTS2 region and month (out of the 3264 possible region-month combinations) together represented over 75% of the risk of pest-host contact with the potential for transfer within the EU, with certain regions of Spain, Italy and Portugal being prominent.

The variance in risk was high and the distribution was heavily skewed to low values. Fig. 4.4.01 illustrates the contact risk distributions of the highest ranked risk, Andalucía in September, and the 30th ranked risk, Veneto in July (see Table 4.4.03). The x-axes are similarly scaled to show how the distribution of risk very rapidly declines to low values. The cut point for the top 5% of the distribution was about 7 times greater in the 1st-ranked than in the 30th-ranked situation.

Table 4.4.03 shows the 30 highest ranked risk cases (region and month) with, for example, Andalucía in September posing the highest risk and representing 7.1% of the total contact risk for all months and NUTS2 regions. The effect of year to year differences in trade on the result is shown by the change in rank in individual years from the overall rank determined by the average of the five year period. For example, Andalucía in September was the highest ranked risk using data from all years, whilst Andalucía in July was more variable in the risk rankings being, for example, 34 places further down the rankings in 2011 compared to the average position.

The variance indicates those regions-months where pest contact risk was particularly variable from year to year and it is of note that, with one exception, the top 20 worst risk cases remained reasonably stable. This indicates that, with a few exceptions, the high risk region-month combinations are fairly robust to the changes in trade between 2010 and 2014.

The risk of contact was also examined in relation to the infestation scenario described earlier and it was confirmed that the ranking of region-month combinations did not change. This is because the infestation rate affected the amount, but not the pattern, of infested imports because nearly all the imports came from the countries of Cluster 1. The risk itself consistently doubled in scenario Av(1), corresponding directly to a doubling in infestation rate in source countries relevant to Europe. The risk did not change in Scenario Av(2) reflecting that a doubling in infestation rate from certain countries did not affect risk to Europe.

In the final model, a proportion of the commodity is destined for retail and a proportion for processing. The results were compared with hypothetical situations where the commodity goes entirely to retail or to processing. In this way we can assess the importance of the assumption concerning the proportion destined for processing. When the retail and processing aspects of risk are disaggregated then, as expected, the patterns of the two were different. To show how the risk rankings differ between retail and processing, the region-month combinations were again ranked according to the final model, and the deviations from this ranking shown when retail alone is considered and when processing alone is considered (Table 4.4.04). The differences when retail alone is considered were in general quite small. Murcia in August was an exception, reflecting the importance of Murcia for orange processing. The small differences between the final model and the retail-only scenario reflected that most of the risk was associated with retail rather than processing. In contrast, when the processing only scenario is considered the outcome was very different from the final model. Those regions which do not process orange clearly dropped greatly in the risk rankings because the risk is zero. In the scenario when the entire commodity goes to processing, the risk rankings showed some large changes from the standard parameterisation of the model. Those regions which did not process the commodity (e.g. Cataluña) showed a large drop in risk because all the risk associated with these locations had been due to retail rather than processing waste. The regions which processed the commodity (e.g. Valencia) showed minor changes in risk ranking compared to the risk in the standard model (which included both retail and processing risks).

Approximately 8.5 times more risk was estimated when the entire commodity went to retail than if the entire commodity went to processing, so per unit of commodity, the risk can be said to be 8.5 times greater associated with retail than processing. In the final model, as parameterised, a mode of 83% of the imported commodity went to retail use and 17% went to processing use. Taking this into account, the risk associated with retail use was overall 8.5 x (83%/17%) = 41.5 times greater than that associated with processing.

The percentages of retail-only risk and of the processing-only risk are also shown in Table 4.4.04, so for example, the most risky region-month combination overall, Andalucía in September, carried 7.1% of the retail risk and 4.3 % of the processing risk; in contrast, Murcia in September carried 1.1% of the retail risk but 14.4% of the total processing risk. The geographical concentration of risk, or the degree to which the risk is concentrated in a few regions-months as opposed to being more spread out, is similar for retail-alone as for the final model. With the processing component of risk, the concentration of risk was greater with comparatively few regions and months representing a large proportion of the total processing risk.

To investigate the effect of processor distribution at NUTS2, the final model was compared with a 'no knowledge' baseline. In the final model, commodity processing was distributed according to the proportion of all fruit and vegetable processors (f). This was compared with an even distribution of processors across the NUTS2 regions within each country (g). In Table 4.4.05, NUTS2 region-month combinations are again ranked according to risk as shown by the final model (f). The difference in ranking (f-g) which occurred is shown when the alternative assumption (g) was made about the geographic distribution of the commodity processors between NUTS2 regions within a country.

The column of the table head 'f-g' shows how the risk rankings changed when an even distribution of processors was used. The changes proved to be relatively small, the most important being in Murcia, where risk would have been underestimated if an even distribution of processors was assumed. The effect on the final model, which included both retail and processing-related risk, was relatively small because most fresh fruit imports go to retail use.

In contrast, when the processing-related risk was examined in isolation, the influence of processor distribution was clearly much larger. The high ranked regions-months remain relatively high in the overall ranking but, for the regions which do no process the commodity, the risk was greatly overestimated when using the baseline assumption represented by (g) (see column headed Pf-Pg, Table 4.4.05). The effect is that the risk becomes less concentrated and is spread out more evenly over the regions. This can be seen by comparison of columns headed '% Risk Pf' (more concentrated pattern) and '% Risk Pg (more even pattern). This is to be expected given the assumption of an even distribution of processing activity in this scenario.

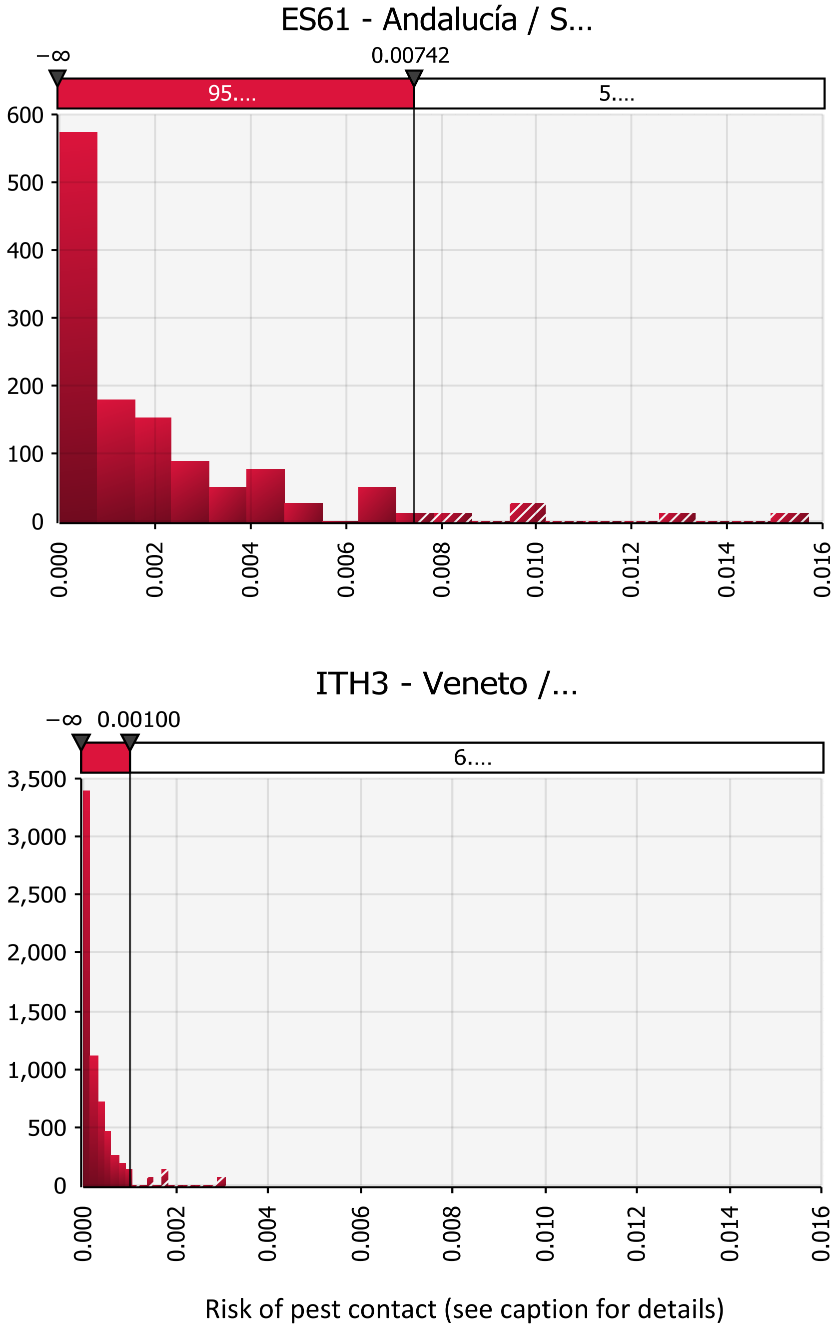


Figure 4.4.01: Frequency distributions of the risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material arriving (100 kg) and vulnerable area accessible by the pest (km^2), shown on the x-axes. The y-axes indicate the number of simulated scenarios falling in each x-axis category. Two region-month combinations are illustrated, corresponding to risk ranks 1 and 30 (Table 4.4.03)

Table 4.4.01: Year to year differences in total Infested commodity, imports and net transhipments, in each Member State (volume: 100 kg) over the period 2010 to 2014. The colour spectrum highlights higher (red) and lower (blue) volumes

	Trade year				
	2010(0)	2011(0)	2012(0)	2013(0)	2014(0)
AUSTRIA	0.07	0.07	0.04	0.05	0.06
BELGIUM (and LUXBG -> 1998)	0.55	0.59	0.30	0.39	0.41
BULGARIA	0.03	0.03	0.00	0.01	0.01
CYPRUS	0.00	0.00	0.00	0.00	0.00
CZECH REPUBLIC (CS->1992)	0.10	0.09	0.05	0.05	0.07
GERMANY (incl DD from 1991)	1.00	0.98	0.59	0.69	0.45
DENMARK	0.13	0.11	0.11	0.12	0.17
ESTONIA	0.01	0.01	0.00	0.01	0.00
SPAIN	4.29	3.54	2.60	3.18	2.83
FINLAND	0.03	0.03	0.02	0.02	0.02
FRANCE	1.03	0.98	0.66	0.85	1.05
UNITED KINGDOM	1.32	1.24	0.55	0.68	0.96
GREECE	0.05	0.03	0.02	0.02	0.01
CROATIA	0.04	0.04	0.03	0.02	0.02
HUNGARY	0.01	0.01	0.01	0.01	0.01
IRELAND	0.15	0.12	0.05	0.05	0.07
ITALY	0.85	1.19	0.54	0.86	0.56
LITHUANIA	0.10	0.08	0.07	0.05	0.04
LUXEMBOURG	0.01	0.01	0.00	0.01	0.01
LATVIA	0.02	0.02	0.01	0.01	0.01
MALTA	0.02	0.02	0.01	0.02	0.02
NETHERLANDS	3.45	3.02	1.65	1.78	1.20
POLAND	0.23	0.22	0.12	0.14	0.17
PORTUGAL	1.11	0.39	0.15	0.28	0.24
ROMANIA	0.07	0.07	0.03	0.04	0.04
SWEDEN	0.34	0.26	0.16	0.22	0.30
SLOVENIA	0.02	0.02	0.01	0.01	0.01
SLOVAKIA	0.02	0.02	0.01	0.01	0.02

2010 = year of trade data

(0) = best estimate of infestation rates as in final model

Table 4.4.02: Differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) under different infestation scenarios in the source countries of the commodity. The colour spectrum highlights higher (red) and lower (blue) volumes

	Infestation cluster scenario		
	Av(0)	Av(1)	Av(2)
AUSTRIA	0.06	0.12	0.06
BELGIUM (and LUXBG -> 1998)	0.46	0.90	0.45
BULGARIA	0.02	0.03	0.02
CYPRUS	0.00	0.00	0.00
CZECH REPUBLIC (CS->1992)	0.07	0.15	0.07
GERMANY (incl DD from 1991)	0.74	1.46	0.74
DENMARK	0.13	0.26	0.13
ESTONIA	0.01	0.01	0.01
SPAIN	3.30	6.59	3.29
FINLAND	0.02	0.05	0.02
FRANCE	0.95	1.88	0.94
UNITED KINGDOM	0.95	1.88	0.97
GREECE	0.03	0.05	0.03
CROATIA	0.03	0.06	0.03
HUNGARY	0.01	0.02	0.01
IRELAND	0.09	0.18	0.09
ITALY	0.80	1.60	0.80
LITHUANIA	0.07	0.13	0.07
LUXEMBOURG	0.01	0.01	0.01
LATVIA	0.01	0.03	0.01
MALTA	0.02	0.03	0.02
NETHERLANDS	2.19	4.38	2.19
POLAND	0.18	0.36	0.18
PORTUGAL	0.42	0.83	0.42
ROMANIA	0.06	0.12	0.06
SWEDEN	0.25	0.49	0.25
SLOVENIA	0.01	0.03	0.01
SLOVAKIA	0.02	0.03	0.02

Av = average trade for all years
(0) = best estimate of infestation rates as in final model
(1) = Infestation rate doubled in Cluster 1 countries
(2) = Infestation rate doubled in Cluster 2 countries
Cluster 1 = US, Japan, S. Korea & S. America,
Cluster 2 = other countries that are known sources

Table 4.4.03: In rank order based on five-year average trade, the NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material arriving (100 kg units) and vulnerable area accessible by pest (km^2). The changes in ranking are shown for individual years. The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular years. The variance indicates those regions-months where pest contact risk was particularly variable from year to year (darker grey)

NUTS2 Region	Month	% of Risk	Change in rank from 5-year average 2010	2011	2012	2013	2014	Vari-ance
ES61 - Andalucía	Sep	7.1%	0	0	0	0	0	0
ES61 - Andalucía	Aug	4.9%	-1	-1	0	0	-2	6
ES51 - Cataluña	Sep	3.8%	-2	-1	-1	0	1	7
ES61 - Andalucía	Oct	3.7%	0	2	1	-3	-2	18
ES30 - Comunidad de Madrid	Sep	3.5%	-1	0	-1	1	2	7
ES52 - Comunidad Valenciana	Sep	3.1%	-3	0	-2	1	1	15
ES51 - Cataluña	Aug	2.6%	-4	-1	2	-1	-1	23
ES30 - Comunidad de Madrid	Aug	2.4%	-5	-3	1	-1	-2	40
ES52 - Comunidad Valenciana	Aug	2.2%	-6	-4	0	-1	-4	69
ES61 - Andalucía	Jul	2.2%	8	-34	-9	4	-17	1606
ES51 - Cataluña	Oct	2.0%	-6	4	0	-5	0	77
ITC4 - Lombardia	Jul	1.9%	-8	3	2	0	-9	158
ES42 - Castilla-la Mancha	Sep	1.9%	-8	-1	0	2	6	105
ES30 - Comunidad de Madrid	Oct	1.8%	-5	4	2	-6	2	85
ES41 - Castilla y León	Sep	1.8%	-8	0	0	2	6	104
ES52 - Comunidad Valenciana	Oct	1.7%	-6	4	2	-6	1	93
ES62 - Región de Murcia	Sep	1.4%	-13	-2	-3	0	3	191
ITF3 - Campania	Jul	1.4%	-11	2	2	-3	-14	334
ES42 - Castilla-la Mancha	Aug	1.3%	-9	-4	2	-5	1	127
ES41 - Castilla y León	Aug	1.3%	-11	-5	2	-5	1	176
PT17 - Lisboa	Aug	1.2%	13	3	-19	-19	-30	1800
ES51 - Cataluña	Jul	1.2%	15	-54	-10	8	-19	3666
ITC4 - Lombardia	Aug	1.1%	-18	6	-8	0	7	473
ES30 - Comunidad de Madrid	Jul	1.1%	14	-56	-12	9	-23	4086
ITF3 - Campania	Sep	1.0%	-20	5	-1	7	-1	476
PT17 - Lisboa	Jul	1.0%	10	-19	-19	-6	-26	1534
ES62 - Región de Murcia	Aug	1.0%	-7	-3	6	-2	-1	99
ES42 - Castilla-la Mancha	Oct	1.0%	-7	6	5	-9	4	207
ES52 - Comunidad Valenciana	Jul	1.0%	17	-55	-9	10	-21	3936
ITH3 - Veneto	Jul	1.0%	-8	4	8	3	-7	202

Table 4.4.04: How risk rankings differ between retail and processing. The top 30 highest ranked risks are listed from the final model; these reflect mostly retail use coupled with a lesser amount of processing use. The deviations from the ranking when retail alone is considered (f-Rf) and when processing alone is considered (f-Pf) are given, together with the percentages of the retail and processing risk which lies in each region-month combination

NUTS2 Region	Month	f-Rf	Retail risk	f-Pf	Proc. risk
ES61 - Andalucía	Sep	0	7.1%	-7	4.3%
ES61 - Andalucía	Aug	0	5.0%	-7	3.0%
ES51 - Cataluña	Sep	0	3.9%	-301	0.0%
ES61 - Andalucía	Oct	0	3.8%	-7	2.3%
ES30 - Comunidad de Madrid	Sep	0	3.6%	-299	0.0%
ES52 - Comunidad Valenciana	Sep	0	3.0%	3	9.1%
ES51 - Cataluña	Aug	0	2.7%	-297	0.0%
ES30 - Comunidad de Madrid	Aug	0	2.5%	-296	0.0%
ES52 - Comunidad Valenciana	Aug	-1	2.1%	4	6.3%
ES61 - Andalucía	Jul	1	2.2%	-2	1.3%
ES51 - Cataluña	Oct	0	2.0%	-293	0.0%
ITC4 - Lombardia	Jul	0	1.9%	-2	1.1%
ES42 - Castilla-la Mancha	Sep	0	1.9%	-291	0.0%
ES30 - Comunidad de Madrid	Oct	0	1.9%	-290	0.0%
ES41 - Castilla y León	Sep	0	1.8%	-289	0.0%
ES52 - Comunidad Valenciana	Oct	0	1.6%	10	4.8%
ES62 - Región de Murcia	Sep	-7	1.1%	16	14.4%
ITF3 - Campania	Jul	1	1.4%	5	1.2%
ES42 - Castilla-la Mancha	Aug	1	1.3%	-285	0.0%
ES41 - Castilla y León	Aug	1	1.3%	-284	0.0%
PT17 - Lisboa	Aug	1	1.2%	1	0.7%
ES51 - Cataluña	Jul	1	1.2%	-282	0.0%
ITC4 - Lombardia	Aug	1	1.1%	2	0.6%
ES30 - Comunidad de Madrid	Jul	1	1.1%	-280	0.0%
ITF3 - Campania	Sep	0	1.0%	10	0.9%
PT17 - Lisboa	Jul	-1	1.0%	-1	0.5%
ES62 - Región de Murcia	Aug	-10	0.8%	25	10.1%
ES42 - Castilla-la Mancha	Oct	2	1.0%	-276	0.0%
ES52 - Comunidad Valenciana	Jul	-2	0.9%	19	2.8%
ITH3 - Veneto	Jul	1	1.0%	7	0.6%

Table 4.4.05: How risk rankings differ in relation to alternative assumptions made about the location of processing based on the location of all fruit and vegetable processing enterprises, as in the final model (f), or an equal distribution across all NUTS2 regions within a country (g). The 30 highest ranked risks are listed in order from the final model (f) and the deviation when Assumption (g) is employed instead (f-g), and similarly when processing risk alone is considered (Pf-Pg). The percentage of the processing risk which lies in each of the top 30 region-month combinations is also shown. For example, Andalucía in September (which had the highest overall rank for total risk), showed no change in ranking when all risks were considered (f-g) but increased by 6 places when just processing risks were considered (Pf-Pg); it represented 4.3% of processing risk under Assumption f and 2.6% under Assumption (g)

NUTS2 Region	Month	f-g	Pf-Pg	% Risk Pf	% Risk Pg
ES61 - Andalucía	Sep	0	6	4.3%	2.6%
ES61 - Andalucía	Aug	0	-2	3.0%	1.8%
ES51 - Cataluña	Sep	0	289	0.0%	1.5%
ES61 - Andalucía	Oct	0	-11	2.3%	1.3%
ES30 - Comunidad de Madrid	Sep	0	292	0.0%	1.7%
ES52 - Comunidad Valenciana	Sep	0	-7	9.1%	1.8%
ES51 - Cataluña	Aug	0	275	0.0%	1.1%
ES30 - Comunidad de Madrid	Aug	0	277	0.0%	1.2%
ES52 - Comunidad Valenciana	Aug	-1	-20	6.3%	1.2%
ES61 - Andalucía	Jul	1	-33	1.3%	0.8%
ES51 - Cataluña	Oct	0	263	0.0%	0.8%
ITC4 - Lombardia	Jul	-1	-37	1.1%	0.7%
ES42 - Castilla-la Mancha	Sep	1	303	0.0%	2.7%
ES30 - Comunidad de Madrid	Oct	0	267	0.0%	0.9%
ES41 - Castilla y León	Sep	0	299	0.0%	2.2%
ES52 - Comunidad Valenciana	Oct	0	-29	4.8%	0.9%
ES62 - Región de Murcia	Sep	-6	-3	14.4%	2.2%
ITF3 - Campania	Jul	1	-29	1.2%	0.8%
ES42 - Castilla-la Mancha	Aug	1	296	0.0%	1.9%
ES41 - Castilla y León	Aug	1	287	0.0%	1.5%
PT17 - Lisboa	Aug	1	-26	0.7%	0.8%
ES51 - Cataluña	Jul	1	230	0.0%	0.5%
ITC4 - Lombardia	Aug	1	-63	0.6%	0.4%
ES30 - Comunidad de Madrid	Jul	0	232	0.0%	0.5%
ITF3 - Campania	Sep	0	-44	0.9%	0.6%
PT17 - Lisboa	Jul	-1	-28	0.5%	0.6%
ES62 - Región de Murcia	Aug	-10	-12	10.1%	1.5%
ES42 - Castilla-la Mancha	Oct	2	286	0.0%	1.4%
ES52 - Comunidad Valenciana	Jul	-3	-55	2.8%	0.5%
ITH3 - Veneto	Jul	1	-29	0.6%	0.7%

4.4.2. Apple model

Sensitivity of infested volume entering Member States

The trade volume entering different states from different source countries varies from year to year. The infested volume entering Member States is the final output from Module 1 and gives the amount of infested material arriving in each Member State. The pattern of infested volume entering Member States was in broad terms reasonably stable over the years 2010 to 2014, with a single high risk country (UK) and the low risk countries (the other MS) remaining consistently so throughout the period (Table 4.4.06). However, there were some changes in risk with, for example, the infested volumes entering the UK being 2.4 times greater in 2010 than in 2014.

The different source countries of the pest concerned have different patterns of export to the EU so any differences in infestation rates in the commodity from the different source countries are expected to result in different risk patterns within the EU. To gain some understanding of the potential importance of such effects, scenarios were simulated in which infestation rates from selected source countries were increased. Doubling the infestation rate of imports from Cluster 1 (Canada) had a minor effect on infested import volumes but doubling infestation from Cluster 2 (US) nearly doubled volumes entering the main importing Member State, the UK (Table 4.4.07). The result is therefore much more sensitive to pest infestation rate in imports from the US, caused by the greater trade volume from this country.

Sensitivity of risk of pest contact

The risk of pest contact is the final model result presented in the final step of Module 2. The risk of pest contact is calculated as the product of the volume of the infested material volume arriving (100 kg) and vulnerable area accessible by the pest (km^2).

The risk of contact was calculated for every NUTS2 region in every month of the year. The results were ranked with the highest risk at the top. The top 50 most risky combinations of NUTS2 region and month (out of 3264 possible region-month combinations) together represented over 60% of the risk of pest-host contact with the potential for transfer within the EU, with apple-growing regions of the UK dominating the risk profile. Nonetheless, the risk was arguably more diffuse than in the orange pest case study where 75% of the risk was accounted for by the top 50 most risky region-month combinations.

The variance in risk was high and the distribution was skewed to low values. Fig. 4.4.02 illustrates the contact risk distributions of the highest ranked risk, East Anglia in May, and the 30th ranked risk, East Anglia in October (see Table 4.4.08). The x-axes are similarly scaled to show how the distribution of risk very rapidly declines to low values. The cut point for the top 5% of the distribution was about 5 times greater in the 1st-ranked than in the 30th-ranked situation. The corresponding figure for the orange case study was 7 times, again indicating a more diffuse risk pattern in the apple case study.

Table 4.4.08 shows the 30 highest ranked risk cases (region and month) with, for example, East Anglia in May having the highest risk and representing 4% of the total contact risk for all months and NUTS2 regions. The effect of year to year differences in trade on the result is shown by the change in rank in individual years from the overall rank determined by the average of the five year period. For example, East Anglia in May exhibited consistently high ranking in all years, being ranked first in 2010, 2013 and 2014 and second in 2011 and 2012). East Anglia in August proved the most variable in the top 30, being for example, 16 places further down the rankings in 2012, and 16 places higher in 2013, compared to the average position.

The variance indicates those regions-months where pest contact risk was particularly variable from year to year and variability between years certainly existed over the period examined. In context, however, the range of variability was no more than 18 places in the risk rankings, so though not as robust as the situation with the orange case study, the high-risk region-month combinations are fairly stable with respect to the changes in trade between 2010 and 2014.

The risk of contact was also examined in relation to the infestation scenarios described earlier. In this case some small changes in risk ranking occurred, the largest in the top 30 being associated with East Anglia in October (Table 4.4.09); this was because a larger proportion of commodity than usual came from Canada

(Cluster 1) in October. In most cases commodity imports were dominated by the US (Cluster 2) reflecting the 95 to 99% change in risk seen in Table 4.4.09 caused by the doubling of the infestation rate of US imports imposed for the sensitivity analysis. Though the results indicate a high dependency of risk on the main exporter (US), cases such as East Anglia in August indicate that a few exceptions to this rule exist.

In the final model, a proportion of the commodity is destined for retail and a proportion for processing. The results are compared with hypothetical situations where the entire commodity goes to retail or all the commodity goes to processing. In this way we can assess the importance of the assumption concerning the proportion destined for processing. When the retail and processing aspects of risk are disaggregated then, as expected, the patterns of the two were different. To show how the risk rankings differ between retail and processing, the region-month combinations were again ranked according to the final model, and the deviations from this ranking shown when the retail alone scenario is considered and when the processing alone scenario is considered (Table 4.4.10). The differences when retail alone is considered were in general, quite small. East Yorkshire and North Lincolnshire in May showed the largest change reflecting the importance of these regions in general food processing. The differences when processing alone was considered were larger, with changes of up to 20 places in the ranking compared to the picture for risk as a whole. Certain regions had larger numbers of processing enterprises, e.g. East Yorkshire and Lincolnshire and East Anglia, whilst others had smaller numbers, e.g. Hampshire and Essex.

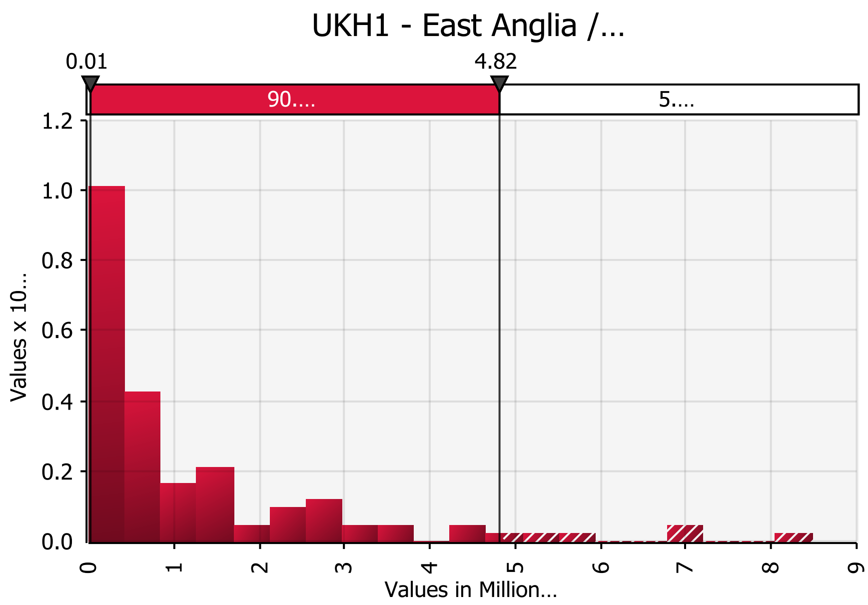
Approximately 1.8 times more risk was estimated to be associated if the entire commodity went to retail than if the entire commodity went to processing, so per unit of commodity, the risk can be said to be 1.8 times greater when it is associated with retail rather than processing. In the final model as parameterised, for the majority of countries a mode of 76% of the imported commodity went to retail use and 24% went to processing use. Taking this into account, therefore, the risk associated with retail use was overall approximately 1.8 x (76%/24%) = 5.7 times greater than that associated with processing use.

The percentage of retail-only risk and of the processing-only risk are also shown in Table 4.4.10, so for example, the most risky region-month combination overall, East Anglia in May, carried 3.8% of the retail risk and 4.7 % of the processing risk. The geographical concentration of risk, or the degree to which the risk is concentrated in a few regions-months as opposed to being more spread out, was similar for retail and processing component of risk.

To investigate the effect of processor distribution at NUTS2 level, the final model was compared with a 'no knowledge' baseline. In the final model, commodity processing was distributed according to the proportion of all fruit and vegetable processors (f). This was compared with an even distribution of processors across the NUTS2 regions within each country (g). In Table 4.4.11, NUTS2 region-month combinations are again ranked according risk as shown by the final model (f). The difference in ranking (f-g) which occurred is shown when the alternative assumption (g) was made about the geographic distribution of the commodity processors between NUTS2 regions within a country.

The column of the table head 'f-g' shows how the risk rankings changed (for risk as a whole) when an even distribution of processors was used. The changes proved to be relatively small, the most important being in East Anglia, where risk would have been underestimated if an even distribution of processors had been assumed. The effect on the final model including both retail and processing-related risk was relatively small.

As expected, when the processing-related risk was examined in isolation, the influence of processor distribution was larger. Again risk in particular regions would be underestimated and in others overestimated, by up to 33 places in the risk rankings. There was no indication that the pattern of risk was more or less concentrated, but there were some differences in pattern which were far less pronounced than was the case in the orange case study.



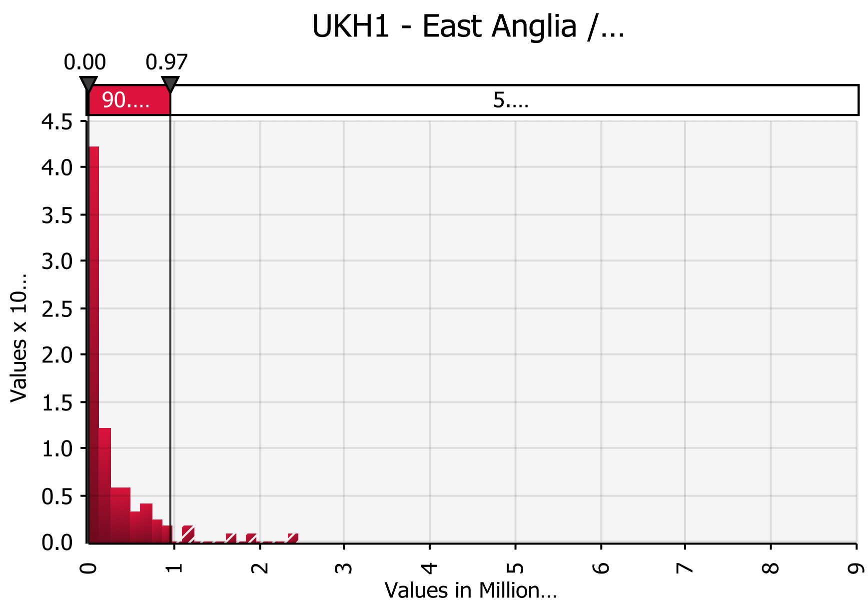


Figure 4.4.02: Frequency distributions of the risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material arriving (100 kg units) and vulnerable area accessible by the pest (km^2), shown on the x-axes. The y-axes indicate the number of simulated scenarios falling in each x-axis category. Two region-month combinations are illustrated, corresponding to risk ranks 1 and 30 (Table 4.4.08)

Table 4.4.06: Year to year differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) over the period 2010 to 2014. The colour spectrum highlights higher (red) and lower (blue) volumes

	Trade year				
	2010(0)	2011(0)	2012(0)	2013(0)	2014(0)
AUSTRIA	0.00	0.00	0.00	0.00	0.00
BELGIUM (and LUXBG -> 1998)	0.09	0.05	0.03	0.01	0.01
BULGARIA	0.00	0.00	0.00	0.00	0.00
CYPRUS	0.00	0.00	0.00	0.00	0.00
CZECH REPUBLIC (CS->1992)	0.00	0.00	0.00	0.00	0.00
GERMANY (incl DD from 1991)	0.08	0.06	0.03	0.01	0.00
DENMARK	0.00	0.00	0.00	0.00	0.00
ESTONIA	0.00	0.00	0.00	0.00	0.00
SPAIN	0.00	0.05	0.04	0.07	0.06
FINLAND	0.54	0.26	0.47	0.62	0.37
FRANCE	0.01	0.01	0.02	0.04	0.02
UNITED KINGDOM	11.11	5.78	5.47	6.01	4.62
GREECE	0.00	0.00	0.00	0.00	0.00
CROATIA	0.00	0.00	0.00	0.00	0.00
HUNGARY	0.00	0.00	0.00	0.00	0.00
IRELAND	0.19	0.09	0.12	0.08	0.11
ITALY	0.00	0.00	0.00	0.00	0.00
LITHUANIA	0.00	0.00	0.04	0.03	0.02
LUXEMBOURG	0.00	0.00	0.00	0.00	0.00
LATVIA	0.00	0.00	0.00	0.00	0.00
MALTA	0.00	0.00	0.00	0.00	0.00
NETHERLANDS	0.04	0.10	0.04	0.02	0.01
POLAND	0.00	0.00	0.00	0.00	0.00
PORTUGAL	0.00	0.00	0.00	0.00	0.00
ROMANIA	0.00	0.00	0.00	0.00	0.00
SWEDEN	0.31	0.11	0.19	0.08	0.04
SLOVENIA	0.00	0.00	0.00	0.00	0.00
SLOVAKIA	0.00	0.00	0.00	0.00	0.00

2010 = year of trade data

(0) = best estimate of infestation rates as in final model

Table 4.4.07: Differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) under different infestation scenarios in the source countries of the commodity. The colour spectrum highlights higher (red) and lower (blue) volumes

	Infestation cluster scenario		
	Av(0)	Av(1)	Av(2)
AUSTRIA	0.00	0.00	0.00
BELGIUM (and LUXBG -> 1998)	0.03	0.03	0.06
BULGARIA	0.00	0.00	0.00
CYPRUS	0.00	0.00	0.00
CZECH REPUBLIC (CS->1992)	0.00	0.00	0.00
GERMANY (incl DD from 1991)	0.03	0.03	0.06
DENMARK	0.00	0.00	0.00
ESTONIA	0.00	0.00	0.00
SPAIN	0.05	0.06	0.10
FINLAND	0.45	0.45	0.90
FRANCE	0.02	0.02	0.04
UNITED KINGDOM	6.60	7.02	12.77
GREECE	0.00	0.00	0.00
CROATIA	0.00	0.00	0.00
HUNGARY	0.00	0.00	0.00
IRELAND	0.12	0.12	0.23
ITALY	0.00	0.00	0.00
LITHUANIA	0.02	0.03	0.05
LUXEMBOURG	0.00	0.00	0.00
LATVIA	0.00	0.00	0.00
MALTA	0.00	0.00	0.00
NETHERLANDS	0.04	0.04	0.08
POLAND	0.00	0.00	0.00
PORTUGAL	0.00	0.00	0.00
ROMANIA	0.00	0.00	0.00
SWEDEN	0.15	0.15	0.29
SLOVENIA	0.00	0.00	0.00
SLOVAKIA	0.00	0.00	0.00

Av = average trade for all years

(0) = best estimate of infestation rates as in final model

(1) = Infestation rate doubled in Cluster 1 countries

(2) = Infestation rate doubled in Cluster 2 countries

Cluster 1 = Canada, Cluster 2 = US (Apple model)

Table 4.4.08: In rank order based on five-year average trade, the NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by the pest (km^2). The changes in ranking are shown for individual years. The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular years. The variance indicates those regions-months where pest contact risk was particularly variable from year to year (darker grey)

NUTS2 Region	Month	% of Risk	Change in rank from 5-year average 2010	2011	2012	2013	2014	Variance
UKH1 - East Anglia	May	4.0%	0	-1	-1	0	0	2
UKH1 - East Anglia	Jun	2.7%	-3	1	-1	-1	0	12
UKH1 - East Anglia	Jul	2.5%	-6	0	2	1	-2	45
UKK1 - Gloucestershire, Wiltshire and Bristol/Bath area	May	2.3%	2	-1	-1	-1	1	8
UKJ1 - Berkshire, Buckinghamshire and Oxfordshire	May	2.2%	2	-2	-3	-1	1	19
UKF2 - Leicestershire, Rutland and Northamptonshire	May	2.0%	2	-3	-4	-5	0	54
UKJ3 - Hampshire and Isle of Wight	May	1.6%	1	-8	-6	-7	-2	154
UKF1 - Derbyshire and Nottinghamshire	May	1.6%	1	-8	-6	-7	-2	154
UKK1 - Gloucestershire, Wiltshire and Bristol/Bath area	Jun	1.6%	-6	5	-8	0	2	129
UKJ1 - Berkshire, Buckinghamshire and Oxfordshire	Jun	1.5%	-6	4	-9	0	2	137
UKH3 - Essex	May	1.5%	3	-8	-5	-8	-1	163
UKK1 - Gloucestershire, Wiltshire and Bristol/Bath area	Jul	1.5%	-11	2	8	5	-5	239
UKJ1 - Berkshire, Buckinghamshire and Oxfordshire	Jul	1.4%	-13	2	7	5	-5	272
UKF2 - Leicestershire, Rutland and Northamptonshire	Jun	1.4%	-4	6	-13	1	3	231
UKG1 - Herefordshire, Worcestershire and Warwickshire	May	1.3%	5	-8	-5	-9	2	199
UKJ4 - Kent	May	1.3%	5	-9	-6	-12	2	290
UKF2 - Leicestershire, Rutland and Northamptonshire	Jul	1.3%	-13	5	8	5	-6	319
UKH2 - Bedfordshire and Hertfordshire	May	1.2%	6	-11	-7	-12	-1	351
UKE1 - East Yorkshire and Northern Lincolnshire	May	1.2%	6	-12	-7	-12	-1	374
UKH1 - East Anglia	Aug	1.2%	-7	3	-16	16	-15	795
UKG3 - West Midlands	May	1.1%	7	-12	-8	-14	-1	454
UKJ3 - Hampshire and Isle of Wight	Jun	1.1%	-2	9	-11	1	7	256
UKF1 - Derbyshire and Nottinghamshire	Jun	1.1%	-2	9	-12	1	7	279
UKJ3 - Hampshire and Isle of Wight	Jul	1.0%	-16	4	13	8	-6	541
UKF1 - Derbyshire and Nottinghamshire	Jul	1.0%	-16	4	13	7	-7	539
UKH3 - Essex	Jun	1.0%	-2	8	-14	1	5	290
UKG2 - Shropshire and Staffordshire	May	1.0%	10	-13	-7	-18	0	642
UKH3 - Essex	Jul	0.9%	-16	2	13	5	-8	518
UKG1 - Herefordshire, Worcestershire and Warwickshire	Jun	0.9%	-3	7	-16	-4	5	355
UKH1 - East Anglia	Oct	0.9%	11	-11	-14	-10	-7	587

Table 4.4.09: With regions-months listed in rank order based on source infestation as parameterised in the final model, Av(0), the changes in risk raking and the percentage changes in risk associated with infestation scenarios where imports from Canada had double the infestation rate, Av(1), and with double the infestation rate for the USA, Av(2). The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular cases

		Change in rank from Av(0)		Change in risk from Av(0)	
NUTS2 Region	Month	Av(1)	Av(2)	Av(1)	Av(2)
UKH1 - East Anglia	May	0	0	5%	95%
UKH1 - East Anglia	Jun	0	0	3%	97%
UKH1 - East Anglia	Jul	0	0	1%	99%
UKK1 - Gloucestershire, Wiltshire and	May	0	0	5%	95%
UKJ1 - Berkshire, Buckinghamshire and	May	0	0	5%	95%
UKF2 - Leicestershire, Rutland and Nor	May	0	0	5%	95%
UKJ3 - Hampshire and Isle of Wight	May	0	0	5%	95%
UKF1 - Derbyshire and Nottinghamshi	May	0	0	5%	95%
UKK1 - Gloucestershire, Wiltshire and	Jun	0	0	3%	97%
UKJ1 - Berkshire, Buckinghamshire and	Jun	0	0	3%	97%
UKH3 - Essex	May	0	-1	5%	95%
UKK1 - Gloucestershire, Wiltshire and	Jul	0	1	1%	99%
UKJ1 - Berkshire, Buckinghamshire and	Jul	0	0	1%	99%
UKF2 - Leicestershire, Rutland and Nor	Jun	0	0	3%	97%
UKG1 - Herefordshire, Worcestershire	May	0	0	5%	95%
UKJ4 - Kent	May	0	-1	5%	95%
UKF2 - Leicestershire, Rutland and Nor	Jul	0	1	1%	99%
UKH2 - Bedfordshire and Hertfordshire	May	0	0	5%	95%
UKE1 - East Yorkshire and Northern Lin	May	0	0	5%	95%
UKH1 - East Anglia	Aug	-1	0	1%	99%
UKG3 - West Midlands	May	1	0	5%	95%
UKJ3 - Hampshire and Isle of Wight	Jun	0	0	3%	97%
UKF1 - Derbyshire and Nottinghamshi	Jun	0	0	3%	97%
UKJ3 - Hampshire and Isle of Wight	Jul	-2	0	1%	99%
UKF1 - Derbyshire and Nottinghamshi	Jul	-2	0	1%	99%
UKH3 - Essex	Jun	1	0	3%	97%
UKG2 - Shropshire and Staffordshire	May	-1	0	5%	95%
UKH3 - Essex	Jul	-1	0	1%	99%
UKG1 - Herefordshire, Worcestershire	Jun	-1	0	3%	97%
UKH1 - East Anglia	Oct	6	-6	18%	82%

Table 4.4.10: How risk rankings differ between retail and processing. The 30 highest ranked risks are listed from the final model. The deviations from the ranking when retail alone is considered (f-Rf) and when processing alone is considered (f-Pf) are given, together with the percentages of the retail and processing risk which lies in region/month combination

NUTS2 Region	Month	f-Rf	Retail risk	f-Pf	Proc. risk
UKH1 - East Anglia	May	0	3.8%	0	4.7%
UKH1 - East Anglia	Jun	0	2.6%	0	3.2%
UKH1 - East Anglia	Jul	0	2.5%	0	3.0%
UKK1 - Gloucestershire, Wiltshire and Bris	May	0	2.3%	-2	1.9%
UKJ1 - Berkshire, Buckinghamshire and Ox	May	0	2.3%	-2	1.6%
UKF2 - Leicestershire, Rutland and Northa	May	0	1.9%	2	2.3%
UKJ3 - Hampshire and Isle of Wight	May	0	1.7%	-15	1.0%
UKF1 - Derbyshire and Nottinghamshire	May	0	1.6%	-7	1.3%
UKK1 - Gloucestershire, Wiltshire and Bris	Jun	0	1.6%	-7	1.3%
UKJ1 - Berkshire, Buckinghamshire and Ox	Jun	0	1.6%	-9	1.1%
UKH3 - Essex	May	0	1.5%	-12	1.0%
UKK1 - Gloucestershire, Wiltshire and Bris	Jul	0	1.5%	-6	1.2%
UKJ1 - Berkshire, Buckinghamshire and Ox	Jul	0	1.5%	-12	1.0%
UKF2 - Leicestershire, Rutland and Northa	Jun	-1	1.3%	6	1.5%
UKG1 - Herefordshire, Worcestershire and	May	-1	1.3%	4	1.4%
UKJ4 - Kent	May	2	1.3%	-11	0.9%
UKF2 - Leicestershire, Rutland and Northa	Jul	-1	1.2%	7	1.4%
UKH2 - Bedfordshire and Hertfordshire	May	1	1.3%	-13	0.9%
UKE1 - East Yorkshire and Northern Lincol	May	-7	1.0%	14	2.2%
UKH1 - East Anglia	Aug	-1	1.1%	7	1.4%
UKG3 - West Midlands	May	2	1.2%	-15	0.8%
UKJ3 - Hampshire and Isle of Wight	Jun	2	1.2%	-17	0.7%
UKF1 - Derbyshire and Nottinghamshire	Jun	1	1.1%	-7	0.9%
UKJ3 - Hampshire and Isle of Wight	Jul	1	1.1%	-20	0.7%
UKF1 - Derbyshire and Nottinghamshire	Jul	0	1.1%	-9	0.8%
UKH3 - Essex	Jun	2	1.1%	-14	0.7%
UKG2 - Shropshire and Staffordshire	May	-1	1.0%	3	1.0%
UKH3 - Essex	Jul	1	1.0%	-17	0.7%
UKG1 - Herefordshire, Worcestershire and	Jun	-2	0.9%	3	1.0%
UKH1 - East Anglia	Oct	-3	0.9%	10	1.1%

Table 4.4.11: How risk rankings differ in relation to alternative assumptions made about the location of processing based on the location of all fruit and vegetable processing enterprises, as in the final model (f), or with an equal distribution across all NUTS2 regions within a country (g). The 30 highest ranked risks are listed in order from the final model (f) and the deviation when Assumption (g) is employed instead (f-g), and similarly when processing risk alone is considered (Pf-Pg). The percentage of the processing risk which lies in each of the top 30 region-month combinations is also shown. For example, East Anglia in June (which was 2nd overall in rank for total risk) showed no change in ranking when all risks were considered (f-g) but decreased 3 places when just processing risks were considered (Pf-Pg); it represented 3.2% of processing risk under Assumption (f) and 1.8% under Assumption (g)

NUTS2 Region	Month	f-g	Pf-Pg	% Risk Pf	% Risk Pg
UKH1 - East Anglia	May	0	0	4.7%	2.7%
UKH1 - East Anglia	Jun	0	-3	3.2%	1.8%
UKH1 - East Anglia	Jul	0	-3	3.0%	1.7%
UKK1 - Gloucestershire, Wiltshire and Brist	May	0	-3	1.9%	1.6%
UKJ1 - Berkshire, Buckinghamshire and Oxf	May	0	0	1.6%	1.7%
UKF2 - Leicestershire, Rutland and Northar	May	0	1	2.3%	1.9%
UKJ3 - Hampshire and Isle of Wight	May	0	12	1.0%	1.5%
UKF1 - Derbyshire and Nottinghamshire	May	0	0	1.3%	1.3%
UKK1 - Gloucestershire, Wiltshire and Brist	Jun	-1	-7	1.3%	1.1%
UKJ1 - Berkshire, Buckinghamshire and Oxf	Jun	-1	-2	1.1%	1.2%
UKH3 - Essex	May	2	12	1.0%	1.5%
UKK1 - Gloucestershire, Wiltshire and Brist	Jul	0	-10	1.2%	1.1%
UKJ1 - Berkshire, Buckinghamshire and Oxf	Jul	0	1	1.0%	1.1%
UKF2 - Leicestershire, Rutland and Northar	Jun	-2	-6	1.5%	1.3%
UKG1 - Herefordshire, Worcestershire and	May	1	3	1.4%	1.7%
UKJ4 - Kent	May	1	15	0.9%	1.3%
UKF2 - Leicestershire, Rutland and Northar	Jul	-1	-9	1.4%	1.2%
UKH2 - Bedfordshire and Hertfordshire	May	1	14	0.9%	1.2%
UKE1 - East Yorkshire and Northern Lincoln	May	0	1	2.2%	1.8%
UKH1 - East Anglia	Aug	-3	-28	1.4%	0.8%
UKG3 - West Midlands	May	1	-7	0.8%	0.7%
UKJ3 - Hampshire and Isle of Wight	Jun	1	9	0.7%	1.0%
UKF1 - Derbyshire and Nottinghamshire	Jun	1	-7	0.9%	0.9%
UKJ3 - Hampshire and Isle of Wight	Jul	0	12	0.7%	0.9%
UKF1 - Derbyshire and Nottinghamshire	Jul	-1	-6	0.8%	0.8%
UKH3 - Essex	Jun	1	9	0.7%	1.0%
UKG2 - Shropshire and Staffordshire	May	-2	-5	1.0%	1.0%
UKH3 - Essex	Jul	1	12	0.7%	0.9%
UKG1 - Herefordshire, Worcestershire and	Jun	-1	4	1.0%	1.1%
UKH1 - East Anglia	Oct	-7	-33	1.1%	0.6%

4.4.3. Plum model

Sensitivity of infested volume entering Member States

The trade volume entering different states from different source countries varies from year to year. The infested volume entering Member States is the final output from Module 1 and gives the amount of infested material arriving in each Member State. As with apple, the pattern of infested volume entering Member States was in broad terms reasonably stable over the years 2010 to 2014, with a high risk country (UK) and low risk countries (the other MS) remaining consistently so throughout the period (Table 4.4.12). However, there were soe changes in risk, with the infested volumes entering the UK being 3.2 times greater in 2012 than in 2013.

The different source countries of the pest concerned have different patterns of export to the EU so any differences in infestation rates in the commodity from different source countries are expected to result in different risk patterns within the EU. To gain some understanding of the potential importance of such effects, scenarios were simulated in which infestation rates from selected source countries were increased. Doubling the infestation rate of imports from Cluster 1 (Canada) had a minor effect on infested import volumes but doubling infestation from Cluster 2 (US) nearly doubled volumes entering the chief importing Member State, the UK (Table 4.4.13). The result is therefore much more sensitive to pest infestation rate in the US, caused by the greater trade volume from that country. The implications of pest infestation rate differences between the two source countries were therefore similar for the apple and plum cases.

Sensitivity of risk of pest contact

The risk of pest contact is the final model output presented in the final step of Module 2. The risk of pest contact is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by pest (km^2).

The risk of contact was calculated for every NUTS2 region in every month of the year. The results were ranked with the highest risk at the top. The 50 most risky combinations of NUTS2 region and month together represented over 85% of the risk of pest-host contact with the potential for transfer within the EU, with fruit-growing regions of the UK, Germany and, to a lesser extent, France, dominating the higher end of the risk profile. Nearly one third of all the risk was represented by one region in one month: Kent in August. The risk associated with this case study was more geographically concentrated than that for the orange and apple case studies.

The variance in risk was high and the distribution skewed to low values, but less so than in the other fruit case studies. Fig. 4.4.03 illustrates the contact risk distributions of the highest ranked risk, Kent in August, and the 30^{th} ranked risk, Nord Pas-de-Calais in August (see Table 4.4.14). The x-axes are similarly scaled to show how the distribution of risk very rapidly declines to low values. The cut point for the top 5% of the distribution was about 66 times greater in the 1st-ranked than in the 30^{th}-ranked situation. The corresponding figure for the orange case study was 7 times, again indicating a much more concentrated risk pattern in the plum case study than in the orange case study.

Table 4.4.14 shows the 30 highest ranked risks with, for example, Kent in August having the highest risk and representing 32.9% of the total contact risk. The effect of year to year differences in trade on the result is shown by the change in rank in individual years from the overall rank determined by the average of the five year period. For example, Kent in August exhibited the highest ranking in all years. In contrast the risk associated with Hereford, Worcestershire and Warwickshire proved the most variable in the top 30, being for example, 26 places further down the rankings in 2014, and 6 places higher in 2012, compared to the average picture.

The variance indicates those regions-months where pest contact risk was particularly variable from year to year and variability certainly existed over the period examined. The range of variability had a maximum 30-place shift in risk ranking, so year to year variability was somewhat greater than that seen in the apple and orange case studies.

The risk of contact was also examined in relation to the infestation scenarios described earlier. In this case, changes in risk occurred in a pattern related to the importing characteristics of particular Member States. With the scenario of increased infestation rate from Cluster 1 (Canada), risk increased more in Germany than in France and UK (Table 4.4.15). The converse was true for the scenario of increased infestation from Cluster 2 (US). These changes represented a maximum of 11 places in risk ranking, which is not particularly great, but may be sufficient to alter perceptions of the pattern of risk between Member States, should a shift in infestation rate occur in one of the source countries.

In the final model, a proportion of the commodity is destined for retail and a proportion for processing. The results are compared with hypothetical situations where the entire commodity goes to retail or the entire commodity goes to processing. In this way we can assess the importance of the assumption concerning the proportion destined for processing. When the retail and processing aspects of risk are disaggregated then, as expected, the patterns of the two were different. To show how the risk rankings differ between retail and processing, the region-month combinations were again ranked according to the final model, and the deviations from this ranking shown when retail alone scenario is considered and when processing alone scenario is considered (Table 4.4.16). The differences when retail alone is considered were all very small, a maximum of only one place in the rankings. The differences when processing alone was considered were larger but in general quite small with changes of up to 9 places in the ranking compared to the picture for risk as a whole. This indicates that the pattern of risk associated with retail and processing differs less than for the other fruit case studies. As can be seen in the top 30 risks, Brandenburg was an exception. This was because no food processing enterprises are listed in the relevant EU database for this region; the processing risk is therefore zero.

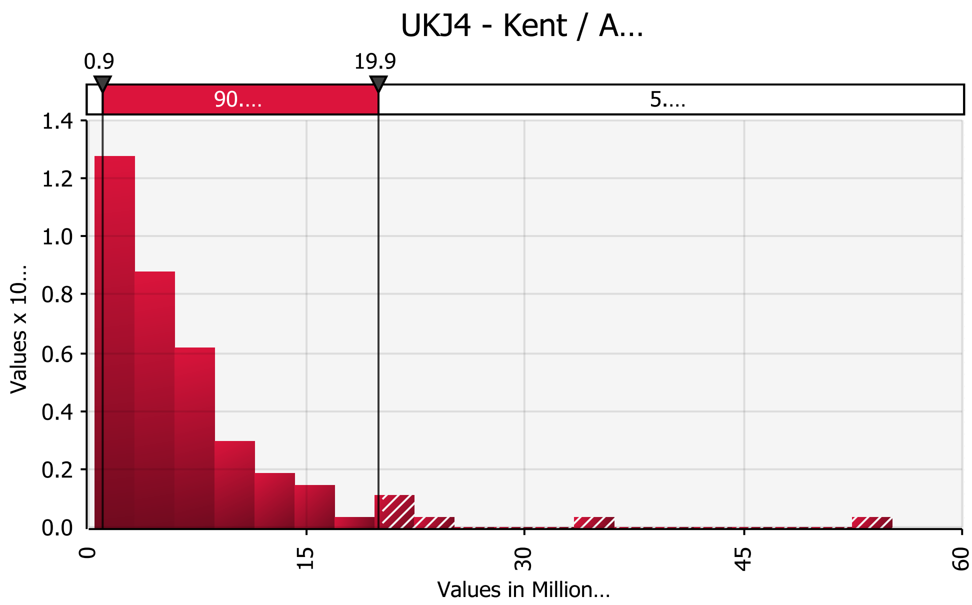
Approximately 1.6 times more risk was estimated to be associated if the entire commodity went to retail than if the entire commodity went to processing, so per unit of commodity, the risk can be said to be 1.6 times greater associated with retail than processing. In the final model as parameterised, a mode of 95% of the imported commodity went to retail use and 5% went to processing use. Taking this into account, therefore, the risk associated with retail use was overall 1.6 x (95%/5%) = 30.4 times greater than that associated with processing use.

The percentage of retail-only risk and of the processing-only risk are also shown in Table 4.4.16, so for example, the most risky region-month combination overall, Kent in August, carried 33.1% of the retail risk and 26.6 % of the processing risk. The geographical concentration of risk, or the degree to which the risk is concentrated in a few regions-months as opposed to being more spread out, was similar for retail and processing components of risk.

To investigate the effect of processor distribution at NUTS2, the final model was compared with a 'no knowledge' baseline. In the final model, commodity processing was distributed according to the proportion of all fruit and vegetable processors (f). This was compared with an even distribution of processors across the NUTS2 regions within each country (g). In Table 4.4.17, NUTS2 region-month combinations are again ranked according to risk as shown by the final model (f). The difference in ranking (f-g) which occurred is shown when the alternative assumption (g) was made about the geographic distribution of the commodity processors between NUTS2 regions within a country.

The column of the table headed 'f-g' shows how the risk rankings changed (for risk as a whole) when an even distribution of processors was used; the effect on ranking was small, a maximum of two places.

As expected, when the processing-related risk was examined in isolation, the influence of processor distribution was larger. In the top 30 highest ranked risks there was a mixture of regions whose risk ranking was affected only a small amount together with some regions whose ranking dropped by quite large amounts, notably Ile de France and a number of regions in Germany. There, regions were listed as having relatively large numbers of processing enterprises so, by taking the alternative assumption of an even distribution of processors, the risk in these regions was underestimated. In contrast, the risk in Brandenburg was greatly over-estimated by the assumption of an even distribution of processors because there are no processors listed in this region. In general, there was no indication that the pattern of risk was more or less concentrated due to the two assumptions of processing geography.



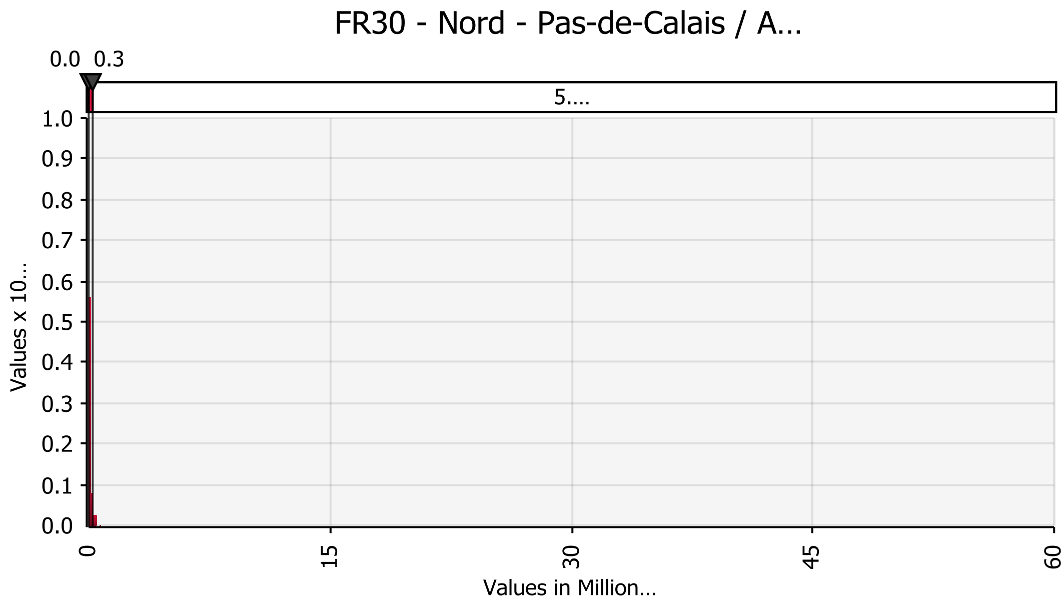


Figure 4.4.03: Frequency distributions of the risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material arriving (100 kg units) and vulnerable area accessible by the pest (km^2), shown on the x-axes. The y-axes indicate the number of simulated scenarios falling in each x-axis category. Two region-month combinations are illustrated, corresponding to risk ranks 1 and 30 (Table 4.4.14)

Table 4.4.12: Year to year differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) over the period 2010 to 2014. The colour spectrum highlights higher (red) and lower (blue) volumes

	Trade year				
	2010(0)	2011(0)	2012(0)	2013(0)	2014(0)
AUSTRIA	0.001	0.002	0.001	0.000	0.001
BELGIUM (and LUXBG -> 1998)	0.040	0.091	0.070	0.019	0.058
BULGARIA	0.000	0.000	0.000	0.000	0.000
CYPRUS	0.000	0.000	0.000	0.000	0.000
CZECH REPUBLIC (CS->1992)	0.001	0.002	0.002	0.000	0.001
GERMANY (incl DD from 1991)	0.044	0.055	0.040	0.010	0.031
DENMARK	0.004	0.006	0.002	0.005	0.010
ESTONIA	0.000	0.001	0.001	0.000	0.001
SPAIN	0.006	0.016	0.008	0.003	0.008
FINLAND	0.000	0.002	0.002	0.001	0.002
FRANCE	0.024	0.063	0.072	0.018	0.028
UNITED KINGDOM	0.415	0.438	0.725	0.228	0.303
GREECE	0.000	0.000	0.000	0.000	0.000
CROATIA	0.000	0.000	0.000	0.000	0.000
HUNGARY	0.000	0.000	0.000	0.000	0.000
IRELAND	0.010	0.011	0.012	0.003	0.005
ITALY	0.008	0.008	0.005	0.002	0.002
LITHUANIA	0.007	0.016	0.027	0.007	0.013
LUXEMBOURG	0.001	0.001	0.001	0.000	0.001
LATVIA	0.000	0.001	0.001	0.000	0.001
MALTA	0.000	0.000	0.000	0.000	0.000
NETHERLANDS	0.033	0.042	0.063	0.014	0.035
POLAND	0.004	0.010	0.008	0.002	0.007
PORTUGAL	0.000	0.001	0.001	0.000	0.001
ROMANIA	0.000	0.000	0.000	0.000	0.001
SWEDEN	0.005	0.005	0.002	0.001	0.004
SLOVENIA	0.000	0.000	0.000	0.000	0.000
SLOVAKIA	0.000	0.000	0.000	0.000	0.000

2010 = year of trade data

(0) = best estimate of infestation rates as in final model

Table 4.4.13: Differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) under different infestation scenarios in the source countries of the commodity. The colour spectrum highlights higher (red) and lower (blue) volumes

	Infestation cluster scenario		
	Av(0)	Av(1)	Av(2)
AUSTRIA	0.001	0.001	0.001
BELGIUM (and LUXBG -> 1998)	0.054	0.078	0.084
BULGARIA	0.000	0.000	0.000
CYPRUS	0.000	0.000	0.000
CZECH REPUBLIC (CS->1992)	0.001	0.002	0.002
GERMANY (incl DD from 1991)	0.036	0.057	0.049
DENMARK	0.005	0.006	0.010
ESTONIA	0.001	0.001	0.001
SPAIN	0.009	0.011	0.015
FINLAND	0.001	0.002	0.002
FRANCE	0.042	0.051	0.074
UNITED KINGDOM	0.422	0.487	0.780
GREECE	0.000	0.000	0.000
CROATIA	0.000	0.000	0.000
HUNGARY	0.000	0.000	0.000
IRELAND	0.008	0.009	0.014
ITALY	0.005	0.006	0.009
LITHUANIA	0.013	0.018	0.021
LUXEMBOURG	0.001	0.001	0.002
LATVIA	0.000	0.001	0.001
MALTA	0.000	0.000	0.000
NETHERLANDS	0.039	0.056	0.060
POLAND	0.006	0.009	0.009
PORTUGAL	0.001	0.001	0.001
ROMANIA	0.000	0.000	0.000
SWEDEN	0.004	0.005	0.006
SLOVENIA	0.000	0.000	0.000
SLOVAKIA	0.000	0.000	0.000

Av = average trade for all years
(0) = best estimate of infestation rates as in final model
(1) = Infestation rate doubled in Cluster 1 countries
(2) = Infestation rate doubled in Cluster 2 countries
Cluster 1 = Canada, Cluster 2 = US (Plum model)

Table 4.4.14: In rank order based on five-year average trade, the NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by the pest (km^2). The changes in ranking are shown for individual years. The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular years. The variance indicates those regions-months where pest contact risk was particularly variable from year to year (darker grey)

NUTS2 Region	Month	% of Risk	Change in rank from 5-year average 2010	2011	2012	2013	2014	Variance
UKJ4 - Kent	Aug	32.9%	0	0	0	0	0	0
UKJ4 - Kent	Jul	6.8%	-2	-3	-3	-3	0	31
UKJ4 - Kent	Sep	6.4%	-3	-1	1	1	-4	28
UKJ2 - Surrey, East and West Sussex	Aug	6.2%	2	2	1	1	1	11
UKG1 - Herefordshire, Worcestershire and Warwickshire	Aug	5.6%	2	2	1	1	1	11
UKJ4 - Kent	Jun	1.5%	1	-30	-8	0	-4	981
UKJ2 - Surrey, East and West Sussex	Jul	1.3%	-8	-8	-3	-6	2	177
DEA1 - Düsseldorf	Aug	1.2%	1	2	-4	-4	0	37
UKJ2 - Surrey, East and West Sussex	Sep	1.2%	-19	-5	3	2	-24	975
UKH1 - East Anglia	Aug	1.2%	2	2	2	0	1	13
UKG1 - Herefordshire, Worcestershire and Warwickshire	Jul	1.2%	-8	-7	0	-3	5	147
FR10 - Île de France	Aug	1.1%	-6	5	3	3	-5	104
UKG1 - Herefordshire, Worcestershire and Warwickshire	Sep	1.1%	-16	-4	6	5	-26	1009
DEA3 - Münster	Aug	0.8%	5	5	-1	-3	3	69
DEF0 - Schleswig-Holstein	Aug	0.8%	5	5	-2	-4	3	79
DE11 - Stuttgart	Aug	0.8%	5	5	-2	-4	3	79
UKF3 - Lincolnshire	Aug	0.8%	-6	-4	4	2	-2	76
DE21 - Oberbayern	Aug	0.7%	6	6	-1	-3	4	98
DEE0 - Sachsen-Anhalt	Aug	0.7%	6	6	-1	-3	4	98
DE94 - Weser-Ems	Aug	0.7%	6	4	-3	-6	2	101
DE40 - Brandenburg	Aug	0.6%	4	2	-3	-6	1	66
DE92 - Hannover	Aug	0.6%	1	0	-3	-7	0	59
DEA2 - Köln	Aug	0.6%	1	0	-3	-8	0	74
FR10 - Île de France	Jul	0.6%	-25	4	8	-4	3	730
DEA4 - Detmold	Aug	0.5%	1	1	-3	-7	1	61
DE71 - Darmstadt	Aug	0.5%	1	1	-4	-7	1	68
DEG0 - Thüringen	Aug	0.5%	1	1	-4	-8	1	83
DE80 - Mecklenburg-Vorpommern	Aug	0.5%	1	1	-4	-8	0	82
FR51 - Pays de la Loire	Aug	0.5%	-16	1	8	6	-21	798
FR30 - Nord - Pas-de-Calais	Aug	0.5%	-16	1	8	6	-21	798

Table 4.4.15: With regions-months listed In rank order based on source infestation as parameterised in the final model, Av(0), the changes in risk raking and the percentage changes in risk associated with infestation scenarios where imports from Canada had double the infestation rate, Av(1), and double the infestation rate in the USA, Av(2). The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular cases

NUTS2 Region	Month	Change in rank from Av(0) Av(1)	Change in rank from Av(0) Av(2)	Change in risk from Av(0) Av(1)	Change in risk from Av(0) Av(2)
UKJ4 - Kent	Aug	0	0	21%	79%
UKJ4 - Kent	Jul	-2	0	5%	95%
UKJ4 - Kent	Sep	1	0	23%	77%
UKJ2 - Surrey, East and West Sussex	Aug	1	0	21%	79%
UKG1 - Herefordshire, Worcestershire	Aug	0	0	21%	79%
UKJ4 - Kent	Jun	-1	0	0%	100%
UKJ2 - Surrey, East and West Sussex	Jul	-5	0	5%	95%
DEA1 - Düsseldorf	Aug	2	-5	67%	33%
UKJ2 - Surrey, East and West Sussex	Sep	1	-1	23%	77%
UKH1 - East Anglia	Aug	1	1	21%	79%
UKG1 - Herefordshire, Worcestershire	Jul	-7	3	5%	95%
FR10 - Île de France	Aug	1	1	23%	77%
UKG1 - Herefordshire, Worcestershire	Sep	0	1	23%	77%
DEA3 - Münster	Aug	4	-1	67%	33%
DEF0 - Schleswig-Holstein	Aug	1	-2	67%	33%
DE11 - Stuttgart	Aug	1	-2	67%	33%
UKF3 - Lincolnshire	Aug	-6	3	21%	79%
DE21 - Oberbayern	Aug	2	-1	67%	33%
DEE0 - Sachsen-Anhalt	Aug	2	-1	67%	33%
DE94 - Weser-Ems	Aug	1	-1	67%	33%
DE40 - Brandenburg	Aug	1	-1	67%	33%
DE92 - Hannover	Aug	1	-3	67%	33%
DEA2 - Köln	Aug	1	-3	67%	33%
FR10 - Île de France	Jul	-11	8	11%	89%
DEA4 - Detmold	Aug	1	-2	67%	33%
DE71 - Darmstadt	Aug	1	-2	67%	33%
DEG0 - Thüringen	Aug	1	-2	67%	33%
DE80 - Mecklenburg-Vorpommern	Aug	1	-2	67%	33%
FR51 - Pays de la Loire	Aug	-9	6	23%	77%
FR30 - Nord - Pas-de-Calais	Aug	-9	6	23%	77%

Table 4.4.16: How risk rankings differ between retail and processing. The 30 highest ranked risks are listed from the final model. The deviations from the ranking when retail alone is considered (f-Rf) and when processing alone is considered (f-Pf) are given, together with the percentages of the retail and processing risk which lies in a region-month combination

NUTS2 Region	Month	f-Rf	Retail risk	f-Pf	Proc. risk
UKJ4 - Kent	Aug	0	33.1%	0	26.6%
UKJ4 - Kent	Jul	0	6.8%	-1	5.5%
UKJ4 - Kent	Sep	0	6.4%	-2	5.2%
UKJ2 - Surrey, East and West Sussex	Aug	0	6.3%	0	5.4%
UKG1 - Herefordshire, Worcestershire and	Aug	0	5.5%	3	7.1%
UKJ4 - Kent	Jun	0	1.6%	-5	1.3%
UKJ2 - Surrey, East and West Sussex	Jul	0	1.3%	-9	1.1%
DEA1 - Düsseldorf	Aug	0	1.2%	-7	1.1%
UKJ2 - Surrey, East and West Sussex	Sep	0	1.2%	-8	1.0%
UKH1 - East Anglia	Aug	0	1.2%	4	1.7%
UKG1 - Herefordshire, Worcestershire and	Jul	0	1.1%	4	1.5%
FR10 - Île de France	Aug	0	1.1%	-9	0.8%
UKG1 - Herefordshire, Worcestershire and	Sep	0	1.1%	4	1.4%
DEA3 - Münster	Aug	0	0.8%	0	1.1%
DEF0 - Schleswig-Holstein	Aug	-1	0.8%	3	1.2%
DE11 - Stuttgart	Aug	1	0.8%	-2	1.0%
UKF3 - Lincolnshire	Aug	-1	0.7%	9	1.4%
DE21 - Oberbayern	Aug	1	0.7%	-1	0.9%
DEE0 - Sachsen-Anhalt	Aug	0	0.7%	-3	0.8%
DE94 - Weser-Ems	Aug	0	0.7%	7	1.2%
DE40 - Brandenburg	Aug	0	0.6%	-1036	0.0%
DE92 - Hannover	Aug	0	0.6%	-4	0.6%
DEA2 - Köln	Aug	0	0.6%	-13	0.5%
FR10 - Île de France	Jul	0	0.6%	-14	0.4%
DEA4 - Detmold	Aug	-1	0.5%	2	0.7%
DE71 - Darmstadt	Aug	1	0.5%	-2	0.6%
DEG0 - Thüringen	Aug	0	0.5%	2	0.7%
DE80 - Mecklenburg-Vorpommern	Aug	0	0.5%	8	0.9%
FR51 - Pays de la Loire	Aug	-1	0.5%	-1	0.5%
FR30 - Nord - Pas-de-Calais	Aug	1	0.5%	-7	0.4%

Table 4.4.17: How risk rankings differ in relation to alternative assumptions made about the location of processing based on the location of all fruit and vegetable processing enterprises, as in the final model (f), or an equal distribution across all NUTS2 regions within a country (g). The 30 highest ranked risks are listed in order from the final model (f) and the deviation when Assumption (g) is employed instead (f-g), and similarly when processing risk alone is considered (Pf-Pg). The percentage of the processing risk which lies in each of the top 30 region-month combinations is also shown. For example, Kent in September (which is 3rd overall in rank for total risk), showed no change in ranking when all risks were considered (f-g) but increased one place when just processing risks were considered (Pf-Pg); it represented 5.2% of processing risk under Assumption (f) and 6.5% under Assumption (g)

NUTS2 Region	Month	f-g	Pf-Pg	% Risk Pf	% Risk Pg
UKJ4 - Kent	Aug	0	0	26.6%	33.4%
UKJ4 - Kent	Jul	0	0	5.5%	6.9%
UKJ4 - Kent	Sep	0	1	5.2%	6.5%
UKJ2 - Surrey, East and West Sussex	Aug	0	-1	5.4%	4.0%
UKG1 - Herefordshire, Worcestershire and	Aug	0	0	7.1%	7.4%
UKJ4 - Kent	Jun	0	4	1.3%	1.6%
UKJ2 - Surrey, East and West Sussex	Jul	0	5	1.1%	0.8%
DEA1 - Düsseldorf	Aug	0	-9	1.1%	0.5%
UKJ2 - Surrey, East and West Sussex	Sep	0	5	1.0%	0.8%
UKH1 - East Anglia	Aug	0	-4	1.7%	0.9%
UKG1 - Herefordshire, Worcestershire and	Jul	0	-1	1.5%	1.5%
FR10 - Île de France	Aug	-1	-35	0.8%	0.2%
UKG1 - Herefordshire, Worcestershire and	Sep	1	0	1.4%	1.4%
DEA3 - Münster	Aug	0	-1	1.1%	0.7%
DEF0 - Schleswig-Holstein	Aug	-1	-5	1.2%	0.6%
DE11 - Stuttgart	Aug	-1	-17	1.0%	0.4%
UKF3 - Lincolnshire	Aug	2	2	1.4%	1.8%
DE21 - Oberbayern	Aug	-1	-18	0.9%	0.4%
DEE0 - Sachsen-Anhalt	Aug	1	8	0.8%	0.7%
DE94 - Weser-Ems	Aug	0	-6	1.2%	0.6%
DE40 - Brandenburg	Aug	0	1036	0.0%	0.6%
DE92 - Hannover	Aug	0	8	0.6%	0.6%
DEA2 - Köln	Aug	0	-14	0.5%	0.3%
FR10 - Île de France	Jul	0	-48	0.4%	0.1%
DEA4 - Detmold	Aug	0	3	0.7%	0.6%
DE71 - Darmstadt	Aug	0	-19	0.6%	0.3%
DEG0 - Thüringen	Aug	0	-1	0.7%	0.5%
DE80 - Mecklenburg-Vorpommern	Aug	0	4	0.9%	0.7%
FR51 - Pays de la Loire	Aug	-1	-14	0.5%	0.3%
FR30 - Nord - Pas-de-Calais	Aug	1	-12	0.4%	0.3%

4.4.4. Wheat model

Sensitivity of infested volume entering Member States

The trade volume entering different states from different source countries varies from year to year. The infested volume entering Member States is the final output from Module 1 and gives the amount of infested material arriving in each Member State. The pattern of infested volume entering Member States was in broad terms less stable for wheat over the years 2010 to 2014 than it was for the three fruit commodity case studies. In particular, there was a sharp decline in potentially infested imports in 2014 compared to earlier years; in the highest risk Member State, Italy, the infested imports were less than half those in any of the previous four years. Three Member States, Spain, Germany and Portugal, which suffered moderate risk in most years had particularly high risk in others: Germany in 2013; Spain in 2012 and 2013; and Portugal in 2012 (Table 4.4.18). The results indicate that the risk of infested commodity entering particular Member States is not readily predicted from historical trade averages due to large year to year trade fluctuations in the wheat imports from the pest-infested source counties of this case study.

The different source countries of the pest concerned have different patterns of export to the EU so any differences in infestation rates in the commodity from different source countries are expected to result in different risk patterns within the EU. To gain some understanding of the potential importance of such effects, scenarios were simulated in which infestation rates from selected source countries were increased. In this case study, varying infestation rates from geographical clusters had differing effects on Spain and Italy, especially. Doubling the infestation rate of imports from Cluster 1 (South American countries) had a large effect on the risk to Spain, and also to Germany, Portugal and Romania. Doubling infestation from Cluster 2 (Australasian countries) had a large effect on the risk to Italy. France and the UK showed increase in risk associated with both clusters (Table 4.4.19). This result reflects differences in the main source of imports to the Member States, and using the model it is possible to attach a value to the degree of change that might be expected under different circumstances.

Sensitivity of risk of pest contact

The risk of pest contact is the final model output presented in the final step of Module 2. The risk of pest contact is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by the pest (km^2).

The risk of contact was calculated for every NUTS2 region in every month of the year. The results were ranked with the highest risk at the top. The top 50 most risky combinations of NUTS2 region and month together represented over 70% of the risk of pest-host contact with the potential for transfer within the EU, with regions of Italy, Spain and the Netherlands dominating the higher end of the risk profile.

The variance in risk was high and the distribution skewed to low values but the distribution had a long tail representing a small probability of high levels of pest contact: Fig. 4.4.04 illustrates the contact risk distributions of the highest ranked risk, Emilia Romagna in April and the 30th ranked risk, Andalucía in April (see Table 4.4.19). The x-axes are similarly scaled to show how the distribution of risk declines to low values as one descends the risk ranking. The cut point for the top 5% of the distribution was about 4 times greater in the 1st-ranked than in the 30th-ranked situation. On average, therefore, the decline in risk is less pronounced than for all the fruit case studies suggesting a less concentrated risk pattern than in the fruit case studies.

Table 4.4.19 shows the 30 highest ranked with, for example, Emilia Romagna in April posing the highest risk and representing 4.1% of the total contact risk. The same region also carried high risk in five other months, March being, on average, the next highest. The effect of year to year differences in trade on the result is shown by the change in rank in individual years from the overall rank determined by the average of the five year period. Year to year variability was much higher than was the case in any of the fruit case studies with 2014, in particular, having a very different risk profile to the four preceding years. Zuid Holland was the least variable across the five year period implying a more consistence pattern of imports than was the case in some other locations. In contrast imports to Emilia Romagna in Italy and to Castilla y Leon, Aragon and Castilla la Mancha in Spain were the most variable. The very large decline in risk ranking seen in these regions, and in others in 2011 and 2014, in particular, were associated with an absence of the usual imports to these regions at those times. It is clear that in the wheat case study risk, although having an underlying pattern across the NUTS2 regions, shows large deviations from this pattern in individual years due primarily to variations in trade patterns from year to year.

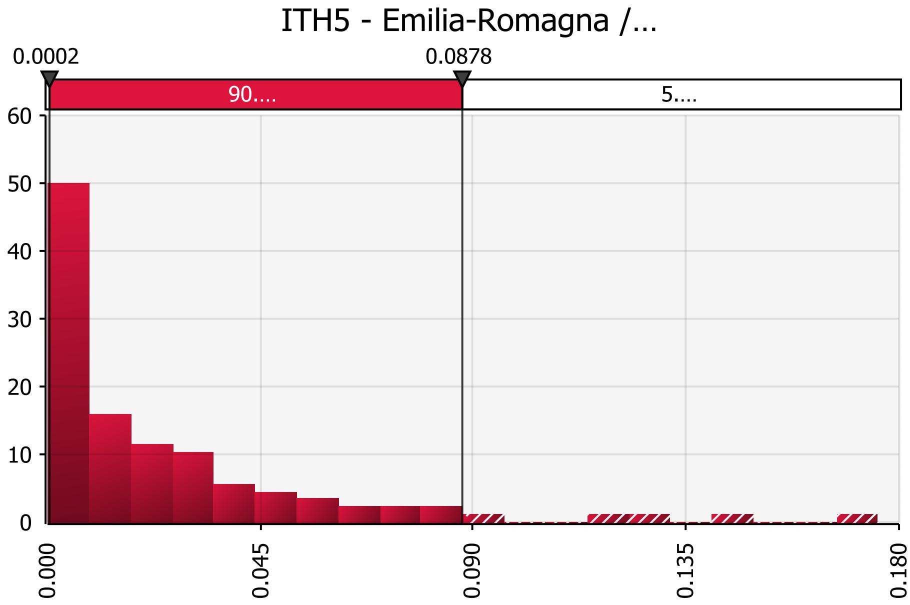
Reflecting the results seen in terms of infested trade volumes, some NUTS2 regions of Spain showed an increased risk associated with a doubling of commodity infestation rates from Cluster 1 sources (South American countries). Doubling infestation from Cluster 2 sources (Australasian countries) had a large effect on the risk on some NUTS2 regions of Italy. In addition, risk in Zuid Holland increased in association with Cluster 2 infestation, reflecting imports to that region (Table 4.4.20). In general the results reflect differences in the main source of imports to the Member States, and it can be seen that in most of the top 30 risks shown there was usually a strong response to either Cluster 1 infestation (e.g. Andalucía in January) or to Cluster 2 infestation (e.g. Veneto in June); less commonly there was a similar response to both Clusters (e.g. Emilia Romagna in February)

These changes represented a maximum of 15 places in risk ranking which is not particularly great but may be sufficient to alter perceptions of the pattern of risk between Member States, should a shift in infestation rate occur in one of the source countries.

In the final model, a proportion of the commodity is destined for milling and a proportion for industrial uses. The results are compared with hypothetical situations where the entire commodity goes to milling or the entire commodity goes to industrial uses. In this way we can assess the importance of the assumption concerning the proportion destined for each. When the milling and industrial aspects of risk are disaggregated then, as expected, the patterns of the two were different. To show how the risk rankings differ between milling and industrial, the region-month combinations were again ranked according to the final model, and the deviations from this ranking shown when milling alone is considered and when industrial use alone is considered (Table 4.4.21). The differences when the milling alone scenario is considered were all very small, a maximum of three places in the rankings, but usually less. The differences when the industrial use alone scenario was considered were mixed, with some region-month combination changing very little from the general picture whilst others showed larger declines in risk ranking because they were regions where little industrial use was recorded. Overall the difference in risk profile between milling and industrial uses may have implications for risk management but the overall geographic patterns had much similarity; for example, the top 7 most risky region-month combinations for milling and industrial uses were within one rank place of each other.

Approximately 1.44 times more risk was estimated to be associated if the entire commodity went to milling than if the entire commodity went to industrial uses, so per unit of commodity, the risk can be said to be 1.44 times greater associated with milling than industrial uses. In the final model as parameterised, a mode of 91% of the imported commodity went to milling use and 9% went to industrial use. Taking this into account, therefore, the risk associated with milling use was overall 1.44 x (91%/9%) = 14.6 times greater than that associated with industrial use.

The percentage of milling-only risk and of the industrial use-only risk are also shown in Table 4.4.21, so for example, the most risky region-month combination overall, Emilia Romagna in April, carried 4.1% of the milling risk and also 4.1 % of the industrial-use risk. The geographical concentration of risk, or the degree to which the risk is concentrated in a few regions-months as opposed to being more spread out, was similar for milling and industrial components of risk.



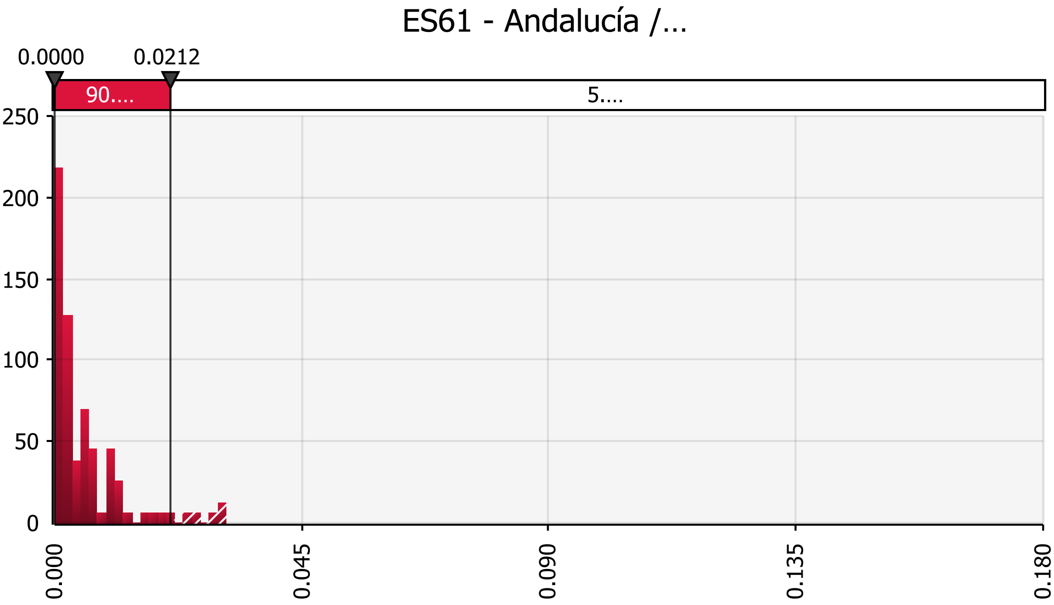


Figure 4.4.04: Frequency distributions of the risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material arriving (100 kg units) and vulnerable area accessible by the pest (km^2), shown on the x-axes. The y-axes indicate the number of simulated scenarios falling in each x-axis category. Two region-month combinations are illustrated, corresponding to risk ranks 1 and 30 (Table 4.4.18)

Table 4.4.18: Year to year differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) over the period 2010 to 2014. The colour spectrum highlights higher (red) and lower (blue) volumes

	Trade year				
	2010(0)	2011(0)	2012(0)	2013(0)	2014(0)
AUSTRIA	0.04	0.05	0.02	0.25	0.01
BELGIUM (and LUXBG -> 1998)	0.22	0.33	0.22	3.17	0.01
BULGARIA	0.00	0.00	0.00	0.08	0.00
CYPRUS	0.00	0.00	0.00	0.00	0.00
CZECH REPUBLIC (CS->1992)	0.00	0.00	0.00	0.00	0.00
GERMANY (incl DD from 1991)	0.40	0.69	0.71	66.56	0.09
DENMARK	0.01	0.07	0.06	0.18	0.00
ESTONIA	0.00	0.00	0.00	0.00	0.00
SPAIN	8.65	9.32	145.68	182.83	0.00
FINLAND	0.03	0.00	0.00	0.00	0.00
FRANCE	0.38	1.49	0.87	0.75	0.06
UNITED KINGDOM	1.81	2.48	0.18	4.63	0.21
GREECE	0.04	0.09	0.01	0.43	0.00
CROATIA	0.00	0.00	0.00	0.00	0.00
HUNGARY	0.00	0.00	0.00	0.00	0.00
IRELAND	0.02	0.03	0.00	0.00	0.00
ITALY	161.64	199.52	214.09	198.48	78.99
LITHUANIA	0.00	0.00	0.00	0.01	0.00
LUXEMBOURG	0.00	0.00	0.00	0.07	0.00
LATVIA	0.00	0.00	0.00	0.00	0.00
MALTA	0.00	0.00	0.00	0.78	0.00
NETHERLANDS	0.16	1.11	0.43	2.93	0.21
POLAND	0.00	0.01	0.00	0.04	0.00
PORTUGAL	0.32	0.12	27.45	2.03	0.00
ROMANIA	0.06	0.19	0.00	6.54	0.00
SWEDEN	0.02	0.00	0.01	0.50	0.00
SLOVENIA	0.01	0.00	0.00	0.00	0.02
SLOVAKIA	0.01	0.00	0.00	0.00	0.00

2010 = year of trade data

(0) = best estimate of infestation rates as in final model

Table 4.4.19: Differences in total Infested commodity, imports and net transhipments, in each Member State (volume units: 100 kg) under different infestation scenarios in the source countries of the commodity. The colour spectrum highlights higher (red) and lower (blue) volumes

	Infestation cluster scenario		
	Av(0)	Av(1)	Av(2)
AUSTRIA	0.10	0.16	0.14
BELGIUM (and LUXBG -> 1998)	0.90	1.70	0.99
BULGARIA	0.00	0.01	0.00
CYPRUS	0.00	0.01	0.00
CZECH REPUBLIC (CS->1992)	0.00	0.00	0.00
GERMANY (incl DD from 1991)	12.23	24.14	12.55
DENMARK	0.09	0.14	0.11
ESTONIA	0.00	0.00	0.00
SPAIN	68.02	134.33	69.72
FINLAND	0.01	0.01	0.01
FRANCE	0.75	1.11	1.12
UNITED KINGDOM	1.35	2.12	1.92
GREECE	0.10	0.15	0.14
CROATIA	0.00	0.00	0.00
HUNGARY	0.01	0.01	0.01
IRELAND	0.02	0.03	0.02
ITALY	170.72	189.21	322.95
LITHUANIA	0.00	0.00	0.00
LUXEMBOURG	0.01	0.02	0.01
LATVIA	0.00	0.00	0.00
MALTA	0.23	0.37	0.33
NETHERLANDS	1.37	2.54	1.57
POLAND	0.06	0.13	0.07
PORTUGAL	6.84	13.63	6.88
ROMANIA	1.86	3.68	1.89
SWEDEN	0.10	0.19	0.10
SLOVENIA	0.00	0.00	0.01
SLOVAKIA	0.01	0.01	0.01

Av = average trade for all years
(0) = best estimate of infestation rates as in final model
(1) = Infestation rate doubled in Cluster 1 countries
(2) = Infestation rate doubled in Cluster 2 countries
Cluster 1 = South American countries;
Cluster 2 = Australasian countries (Wheat model)

Table 4.4.20: In rank order based on five-year average trade, the NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by the pest (km^2). The changes in ranking are shown for individual years. The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular years. The variance indicates those regions-months where pest contact risk was particularly variable from year to year (darker grey)

			Change in rank from 5-year average					
NUTS2 Region	Month	% of Risk	2010	2011	2012	2013	2014	Vari-ance
ITH5 - Emilia-Romagna	Apr	4.1%	-2	-18	-4	0	-626	392220
ITH5 - Emilia-Romagna	Mar	3.7%	-5	-78	-13	-7	1	6328
ITH5 - Emilia-Romagna	Jun	3.5%	2	2	-5	-5	-79	6299
ES61 - Andalucía	Feb	3.3%	-8	-411	2	1	-309	264471
ITH3 - Veneto	Apr	2.7%	-3	-24	-4	3	-639	408931
ITH3 - Veneto	Mar	2.5%	-9	-94	-19	-11	4	9415
ITH5 - Emilia-Romagna	May	2.5%	-7	-2	6	-94	-111	21246
ES41 - Castilla y León	Feb	2.4%	-16	-989	4	3	-674	1E+06
ITH3 - Veneto	Jun	2.3%	5	6	-10	-9	-80	6642
ITG1 - Sicilia	Apr	2.3%	0	-23	-3	6	-834	696130
ITG1 - Sicilia	Jun	2.1%	6	7	-11	-10	-313	98275
ITG1 - Sicilia	Mar	2.0%	-5	-99	-20	-20	9	10707
ITH5 - Emilia-Romagna	Feb	1.8%	11	-395	6	-11	-233	210592
ITH3 - Veneto	May	1.6%	-9	1	11	-99	-126	25880
ES61 - Andalucía	Jan	1.5%	-288	-206	4	8	-38	126904
NL33 - Zuid-Holland	Apr	1.5%	-5	-31	-13	10	-504	255271
NL33 - Zuid-Holland	Jun	1.4%	6	10	-13	-9	-44	2322
ES61 - Andalucía	Mar	1.4%	-44	-125	4	-2	11	17702
ITG1 - Sicilia	May	1.4%	-7	4	13	-391	-274	228191
ITH5 - Emilia-Romagna	Nov	1.3%	7	18	-388	-1036	-1042	2E+06
ES24 - Aragón	Feb	1.3%	-19	-1049	5	9	-706	2E+06
ITH3 - Veneto	Feb	1.3%	16	-423	12	-14	-249	241526
ES41 - Castilla y León	Jan	1.2%	-448	-447	5	13	-127	416836
ES51 - Cataluña	Feb	1.1%	-9	-506	7	5	-356	382927
ITC1 - Piemonte	Jun	1.1%	9	17	-12	-13	-753	567692
ES42 - Castilla-la Mancha	Feb	1.1%	-18	-1070	6	11	-711	2E+06
NL33 - Zuid-Holland	May	1.0%	-10	3	15	-29	-60	4775
ITC1 - Piemonte	Apr	1.0%	1	-30	-7	14	-1034	1E+06
ITF4 - Puglia	Apr	0.9%	0	-31	-7	13	-744	554715
ES61 - Andalucía	Apr	0.9%	-18	-46	-31	19	-586	347158

Table 4.4.21: With regions-months listed in rank order based on source infestation as parameterised in the final model, Av(0), the changes in risk ranking and the percentage changes in risk associated with infestation scenarios where imports from Country Cluster 1 (South America) had double the infestation rate, Av(1), and Country Cluster 2 (Australasia) had double the infestation rate, Av(2). The colour spectrum highlights higher (red) and lower (blue) ranks associated with particular cases

		Change in rank from Av(0)		Change in risk from Av(0)	
NUTS2 Region	Month	Av(1)	Av(2)	Change	Av(2)
ITH5 - Emilia-Romagna	Apr	-3	0	6%	94%
ITH5 - Emilia-Romagna	Mar	0	-1	37%	63%
ITH5 - Emilia-Romagna	Jun	-2	1	0%	100%
ES61 - Andalucía	Feb	3	-6	91%	9%
ITH3 - Veneto	Apr	-4	1	7%	93%
ITH3 - Veneto	Mar	0	-3	38%	62%
ITH5 - Emilia-Romagna	May	-1	0	19%	81%
ES41 - Castilla y León	Feb	5	-9	95%	5%
ITH3 - Veneto	Jun	-7	4	0%	100%
ITG1 - Sicilia	Apr	-5	4	4%	96%
ITG1 - Sicilia	Jun	-8	3	0%	100%
ITG1 - Sicilia	Mar	1	1	31%	69%
ITH5 - Emilia-Romagna	Feb	1	-1	40%	60%
ITH3 - Veneto	May	-6	2	19%	81%
ES61 - Andalucía	Jan	8	-15	100%	0%
NL33 - Zuid-Holland	Apr	-6	1	19%	81%
NL33 - Zuid-Holland	Jun	-8	4	0%	100%
ES61 - Andalucía	Mar	8	-6	79%	21%
ITG1 - Sicilia	May	-4	3	17%	83%
ITH5 - Emilia-Romagna	Nov	-4	2	16%	84%
ES24 - Aragón	Feb	8	-14	95%	5%
ITH3 - Veneto	Feb	1	2	44%	56%
ES41 - Castilla y León	Jan	9	-15	100%	0%
ES51 - Cataluña	Feb	7	-13	90%	10%
ITC1 - Piemonte	Jun	-5	6	0%	100%
ES42 - Castilla-la Mancha	Feb	8	-15	95%	5%
NL33 - Zuid-Holland	May	0	1	30%	70%
ITC1 - Piemonte	Apr	-7	7	4%	96%
ITF4 - Puglia	Apr	-8	7	5%	95%
ES61 - Andalucía	Apr	4	-2	46%	54%

Table 4.4.22: How risk rankings differ between milling (Rf) and industrial uses (Pf). The top 30 highest ranked risks are listed from the final model (f). The deviations from the ranking when milling alone is considered (f-Rf) and when industrial uses alone are considered (f-Pf) are given, together with the percentages of the milling and industrial risk which lies in region-month combination

NUTS2 Region	Month	f-Rf	Milling risk	f-Pf	Indust. risk
ITH5 - Emilia-Romagna	Apr	0	4.1%	0	4.1%
ITH5 - Emilia-Romagna	Mar	0	3.7%	0	3.9%
ITH5 - Emilia-Romagna	Jun	0	3.5%	0	3.5%
ES61 - Andalucía	Feb	0	3.3%	0	3.2%
ITH3 - Veneto	Apr	0	2.7%	0	2.6%
ITH3 - Veneto	Mar	-1	2.5%	-1	2.5%
ITH5 - Emilia-Romagna	May	-1	2.5%	1	2.5%
ES41 - Castilla y León	Feb	2	2.6%	-44	0.5%
ITH3 - Veneto	Jun	-1	2.4%	1	2.2%
ITG1 - Sicilia	Apr	1	2.4%	-14	1.1%
ITG1 - Sicilia	Jun	0	2.1%	-17	1.0%
ITG1 - Sicilia	Mar	0	2.0%	-17	0.9%
ITH5 - Emilia-Romagna	Feb	0	1.8%	3	2.0%
ITH3 - Veneto	May	0	1.7%	-1	1.6%
ES61 - Andalucía	Jan	0	1.5%	-2	1.4%
NL33 - Zuid-Holland	Apr	-1	1.4%	7	2.1%
NL33 - Zuid-Holland	Jun	-2	1.4%	5	2.0%
ES61 - Andalucía	Mar	0	1.4%	4	1.6%
ITG1 - Sicilia	May	3	1.5%	-23	0.7%
ITH5 - Emilia-Romagna	Nov	-2	1.3%	0	1.3%
ES24 - Aragón	Feb	1	1.3%	-33	0.5%
ITH3 - Veneto	Feb	-1	1.3%	4	1.4%
ES41 - Castilla y León	Jan	2	1.3%	-63	0.3%
ES51 - Cataluña	Feb	-2	1.1%	13	2.0%
ITC1 - Piemonte	Jun	1	1.1%	-8	0.9%
ES42 - Castilla-la Mancha	Feb	1	1.1%	-27	0.5%
NL33 - Zuid-Holland	May	-1	1.0%	8	1.4%
ITC1 - Piemonte	Apr	1	1.0%	-12	0.8%
ITF4 - Puglia	Apr	0	0.9%	3	1.0%
ES61 - Andalucía	Apr	0	0.9%	7	1.1%

4.5. Consignment model results

4.5.1. Orange model

Four trade chains were identified as pathways of potential pest entry on sweet orange commodity. These four trade chains involved different combinations of ten stages: on arrival; at airport or harbour; in transport to wholesale; at wholesale and storage; in transport to processor; at processor; in transport to retail; at retail; in transport to consumer; and at consumer. In each case, better evidence was available to support an estimate of mean duration of each of these stages than to estimate the variance. Lower limits could be estimated on the basis of the most rapid duration that was logistically practical, but the upper limits were more uncertain.

As a result, the sensitivity analysis focussed on the effect of changes in the upper limits on the distribution of commodity durations along the trade chains. It is not possible to show all the results, but a summary of the distributions of durations associated with the last stage of each of the four trade chains is shown in Fig. 4.5.01. Two scenarios are shown for comparison: the results from the final model as parameterised, and where the upper limit of each stage was 25% longer than that estimated for the final model. A 25% increase was used in the case of the fruit models because they are perishable products, so there was less potential for the commodity to spend longer in each stage than was the case with wheat.

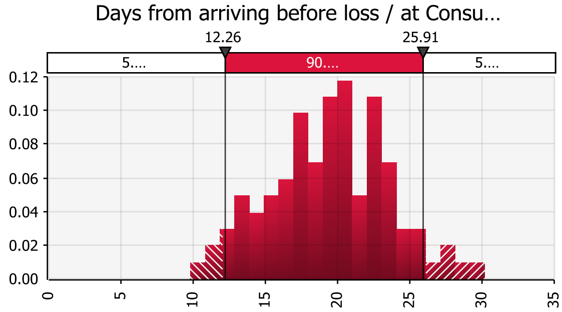
The increase in overall period that the commodity could occur at the final point of the trade chain was between 1.08 and 1.16-fold greater in the scenario where the maximum of each stage was increased by 25% (this being measured by the duration which encompassed 95% of the distribution, Fig. 4.5.01.). The smallest increase was seen in Trade chain 1 so this had the least sensitive assumptions about maximum stage duration. The largest increase was seen in Trade chain 2, so this was correspondingly more sensitive (Table 4.5.01).

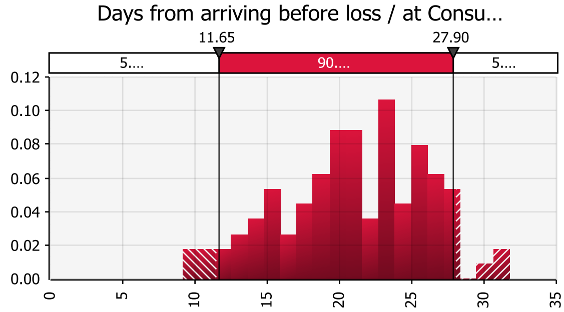
These increases in duration did not reflect a corresponding change in the potential for pest risk. The model incorporates pest mortality along the trade chain and as the time for the commodity to move through the trade chain increases this can lead to reduced infestation rates at later stages of the chain, depending on the biology of the pest concerned. If the later stages carry proportionately high risk of pest release, then an increase in duration can lead to lower risk as a whole. This was particularly true for Trade chain 4 (Table 4.5.01) where, compared to the other trade chains, a higher risk was associated with the last stage in the chain, at the consumer. In the other trade chains, there was less impact of increased trade chain duration on potential pest risk. It was Trade chains 1 and 2 that carried, per unit commodity, the highest relative risk potential for pest release which could lead to introduction. This reflects the higher risk associated with fresh retail rather than processed retail. It is important to remember that these results are per unit commodity travelling along the trade chain so that actual distribution of risk across all trade chains also depends upon the amounts associated with each trade chain.

The @RISK software also provides a built-in function to show the most significant inputs determining any chosen output. Here we determine the key inputs associated with the upper quartile (top 25%) of trade chain durations. Table 4.5.02 shows those input variables where the median associated with the upper quartile of the results differed most (i.e. at least ½ a standard deviation) from the overall median. As can be seen in Table 4.5.02, in Trade chains 1 and 2 which were concerned with the fresh commodity, time spent at the consumer (Trade chain 1) or at the wholesaler and at the consumer (Trade chain 2) were the most influential in determining overall trade chain duration. In contrast, with those trade chains which were concerned with the processed commodity, total trade chain duration was influenced more widely by the various steps in their respective chains.

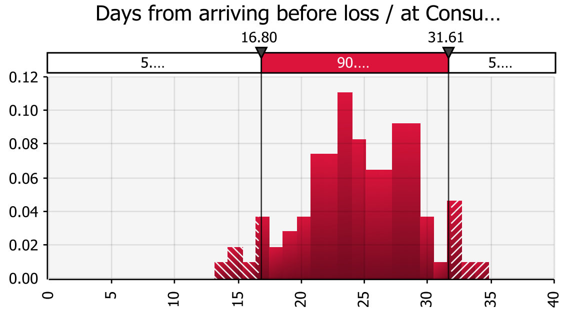
Final model as parameterised **Maximum duration of all stages 25% longer**

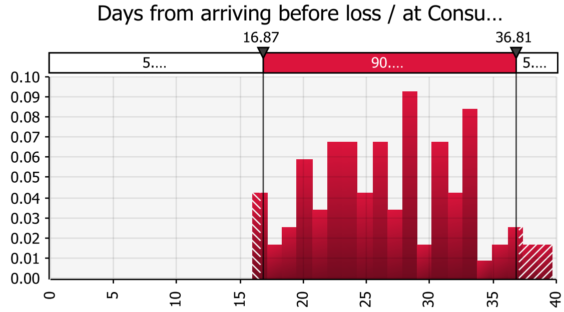
Trade chain 1 (Port to Retail to Consumer)



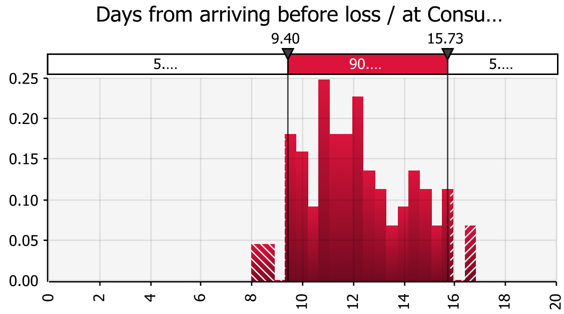


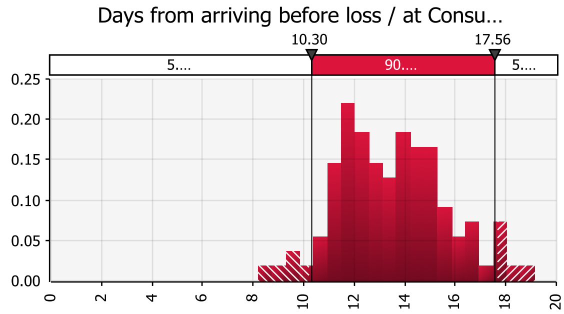
Trade chain 2 (Port to Wholesale/storage to Retail to Consumer)



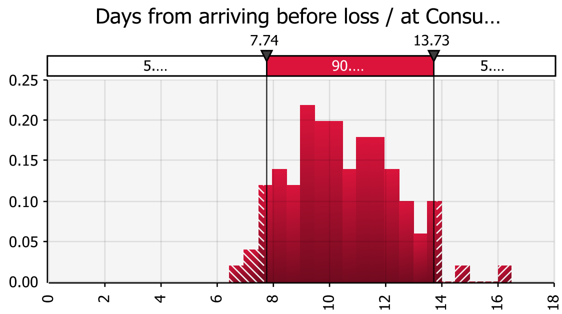


Trade chain 3 (Port to Wholesaler/storage to Processor to Retailer to Consumer)





Trade chain 4 (Port to Processor to Retailer to Consumer)



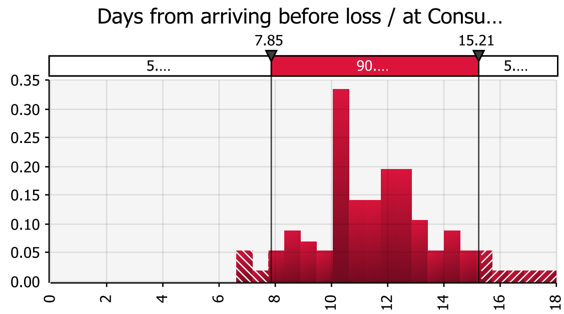


Figure 4.5.01: Sensitivity of the trade chain durations to a 25% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

Table 4.5.01: Summary of the change in risk period and the change in pest risk potential associated with a 25% increase in the maximum duration in all stages of the trade chain. The change in risk period calculated as the shift in the 95th percentile of the duration of the final stage of each trade chain (see Fig. 4.5.01; the change in pest risk potential is the sum of infested volume lost, corrected for infestation level, across all stages of the trade chain. The relative risk potential shows, per unit commodity on the trade chain, the percentage of the risk associated with each trade chain

Trade chain number	Change in risk period (95 %ile)	Change in pest risk potential	Relative risk potential	
			As paramterised	Stage durations + 25%
1	108%	92%	51%	52%
2	116%	89%	43%	42%
3	112%	94%	6%	6%
4	111%	68%	0.1%	0.1%

Table 4.5.02: Key inputs in the scenario where output is in the upper quartile (greater than 75%) of trade chain duration. Input percentiles are shown for each key input; this shows the strength of the association with simulations where the output values were highest, the higher the percentile the stronger the association

Trade chain number	Key inputs associated with long duration scenarios	Input percentiles
1	At consumer	86%
2	At wholesaler and storage; At consumer	81%; 76%
3	At airport; Transport to wholesaler and storage; At retailer	76%; 68%; 67%
4	At processor; At airport; Transport to retail; At consumer	81%; 79%; 68%; 69%

4.5.2. Apple model

Four trade chains were identified as pathways of potential pest entry on desert apple commodity. These four trade chains involved different combinations of ten stages: on arrival; at airport or harbour; in transport to wholesale; at wholesale and storage; in transport to processor; at processor; in transport to retail; at retail; in transport to consumer; and at consumer. In each case better evidence was available to support an estimate of mean duration of each of these stages than to estimate the variance. Lower limits could be estimated on the basis of the most rapid duration that was logistically practical, but the upper limits were more uncertain.

As a result, the sensitivity analysis focussed on the effect of changes in the upper limits on the distribution of commodity durations along the trade chains. It is not possible to show all the results, but to summarise, the distribution of durations associated with the last stage of each of the four trade chains is shown in Fig. 4.5.02. Two scenarios are shown for comparison: the results from the final model as parameterised, and where the upper limit of each stage was 25% longer than that estimated for the final model. A 25% increase was used in the case of the fruit models because it is a perishable product so there was less potential for the commodity to spend longer in each stage than was the case with wheat.

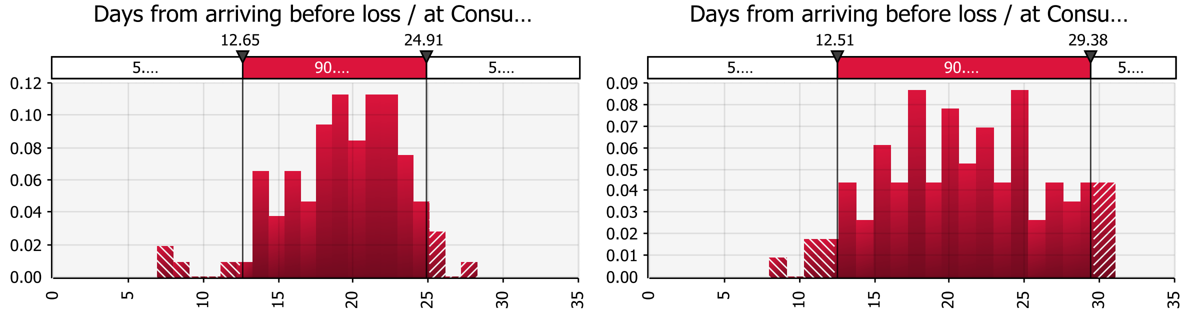
The increase in overall period that the commodity could occur at the final point of the trade chain was between 1.13 and 1.18-fold greater in the scenario where the maximum of each stage was increased by 25% (this being measured by the duration which encompassed 95% of the distribution, Fig. 4.5.02). The smallest increase was seen in Trade chain 3 (therefore, this contained the least sensitive assumptions about maximum stage duration) and the largest increase was seen in Trade chain 1, but in the apple case study, there was little difference between the trade chains (Table 4.5.03).

These increases in duration did not reflect a corresponding change in the potential for pest risk. The model incorporates pest mortality along the trade chain and as the time for the commodity to move through the trade chain increases this can lead to reduced infestation rates at later stages of the chain, depending on the biology of the pest concerned. If the later stages carry proportionately higher risk of pest release, then an increase in duration can lead to lower risk as a whole. This was particularly true for Trade chains 1 and 2 (Table 4.4.04), where compared to the other trade chains, a higher risk was associated with the last stage in the chain, at the consumer. In the other trade chains, there was less impact of increased trade chain duration on potential pest risk. As with the orange case study, it was Trade chains 1 and 2 that carried, per unit commodity, the highest relative risk potential for pest release leading to introduction. This reflects the higher risk associated with fresh retail rather than processed retail. It is important to remember that these results are per unit commodity travelling along the trade chain so that actual distribution of risk across all trade chains also depends upon the amounts associated with each trade chain.

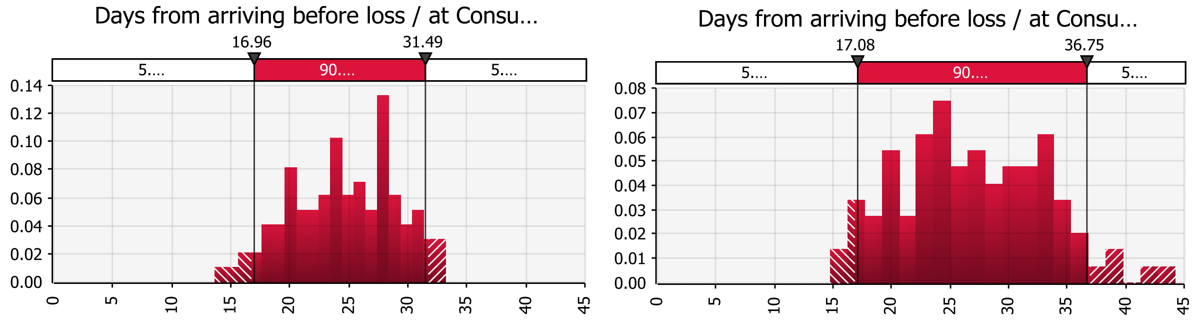
The @RISK software also provides a built-in function to show the most significant inputs determining any chosen output. Here we determine the key inputs associated with the upper quartile (top 25%) of trade chain durations. Table 4.5.04 shows those input variables where the median associated with the upper quartile of the results differed most (i.e. at least half a standard deviation) from the overall median. As can be seen in Table 4.5.04, in Trade chain 1, the total trade chain duration was strongly dependent on the period the commodity spent at the consumer before disposal. Trade chains 2 and 3 were more dependent on other steps in the chain, at wholesale and retail stages (Trade chain 2) and at airport and processor (Trade chain 3). Trade chain 4 showed dependency on some of the transport stages because in this trade chain the time spent at each stage was short, so the effects of transport time have more impact on the overall duration.

Final model as parameterised **Maximum duration of all stages 25% longer**

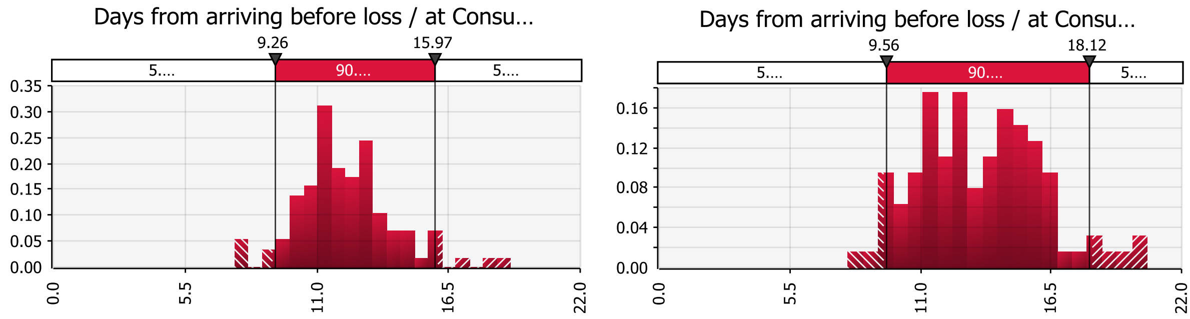
Trade chain 1 (Port to Retail to Consumer)



Trade chain 2 (Port to Wholesale/storage to Retail to Consumer)



Trade chain 3 (Port to Wholesaler/storage to Processor to Retailer to Consumer)



Trade chain 4 (Port to Processor to Retailer to Consumer)

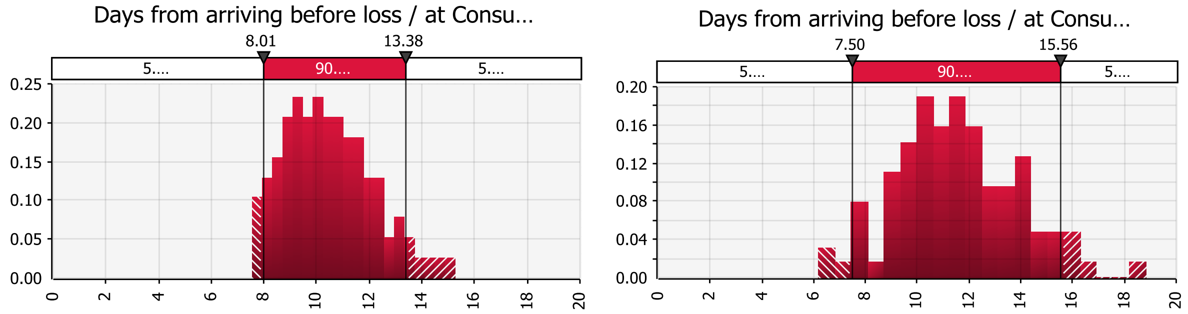


Figure 4.5.02: Sensitivity of the trade chain durations to a 25% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

Table 4.5.03: Summary of the change in risk period and the change in pest risk potential associated with a 25% increase in the maximum duration in all stages of the chain. The change in risk period calculated as the shift in the 95th percentile of the duration of the final stage of each trade chain (see Fig. 4.5.02; the change in pest risk potential is the sum of infested volume lost, corrected for infestation level, across all stages of the chain). The relative risk potential shows, per unit commodity on the trade chain, the percentage of the risk associated with each trade chain

Trade chain number	Change in risk period (95 %ile)	Change in pest risk potential	Relative risk potential	
			As paramterised	Stage durations + 25%
1	118%	92%	54%	55%
2	117%	88%	38%	37%
3	113%	96%	5%	5%
4	116%	98%	3%	3%

Table 4.5.04: Key inputs in the scenario where output is in the upper quartile (greater than 75%) of trade chain duration. Input percentiles are shown for each key input; this shows the strength of the association with simulations where the output values were highest, the higher the percentile the stronger the association

Trade chain number	Key inputs associated with long duration scenarios	Input percentiles
1	At consumer	85%
2	At retailer; At wholesaler and storage; At consumer	78%; 76%; 80%
3	At airport; At processor; At consumer	78%; 73%; 70%
4	At airport; Transport to retail; Transport to processor	80%; 74%; 69%

4.5.3. Plum model

Four trade chains were identified as pathways of potential pest entry on the plum commodity. These four trade chains involved different combinations of ten stages: on arrival; at airport or harbour; in transport to wholesale; at wholesale and storage; in transport to processor; at processor; in transport to retail; at retail; in transport to consumer; and at consumer. In each case better evidence was available to support an estimate of mean duration of each of these stages than to estimate the variance. Lower limits could be estimated on the basis of the most rapid that was logistically practical, but the upper limits were uncertain.

As a result, the sensitivity analysis focussed on the effect of changes in the upper limits on the distribution of commodity durations along the trade chains. It is not possible to show all the results, but to summarise, the distribution of durations associated with the last stage of each of the four trade chains is shown in Fig. 4.5.03. Two scenarios are shown for comparison: the results from the final model as parameterised, and where the upper limit of each stage was 25% longer than that estimated for the final model. A 25% increase was used in the case of the fruit models because it is a perishable product so there was less potential for the commodity to spend longer in each stage than was the case with wheat.

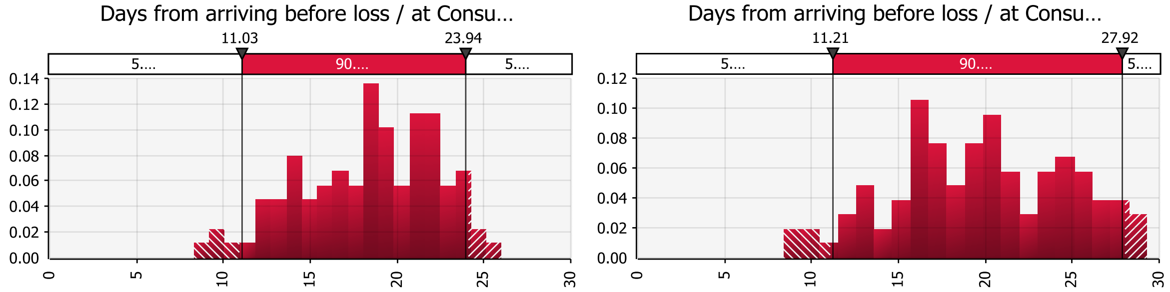
The increase in overall period that the commodity could occur at the final point of the trade chain was between 1.11 and 1.17-fold greater in the scenario where the maximum of each stage was increased by 25% (this being measured by the duration which encompassed 95% of the distribution, Fig. 4.5.03). The smallest increase was seen in Trade chain 2 (therefore, it was least sensitive to assumptions about maximum stage duration) and the largest increase was seen in Trade chain 1, but as with the apple case study, there was little difference between the trade chains in the plum case study (Table 4.5.05).

These increases in duration did not reflect a corresponding change in the potential for pest risk. The model incorporates pest mortality along the trade chain and as the time for the commodity to move through the trade chain increases this can lead to reduced infestation rates at later stages of the chain, depending on the biology of the pest concerned. If the later stages carry proportionately higher risk of pest release, then an increase in duration can lead to lower risk as a whole. In the case of plum, the effects were comparatively small but lowering of risk was most evident in Trade chain 1 and 2 (Table 4.5.05), where a higher risk was associated with the last stage in the chain, fresh fruit waste at the consumer. In the other trade chains, there was almost no impact of increased trade chain duration on potential pest risk. As with the orange and apple case studies, it was Trade chains 1 and 2 that carried, per unit commodity, the highest relative risk potential for pest release which could lead to introduction. This reflects the higher risk associated with fresh retail rather than processed retail. It is important to remember that these results are per unit commodity travelling along the trade chain so that actual distribution of risk across all trade chains also depends upon the amounts associated with each trade chain.

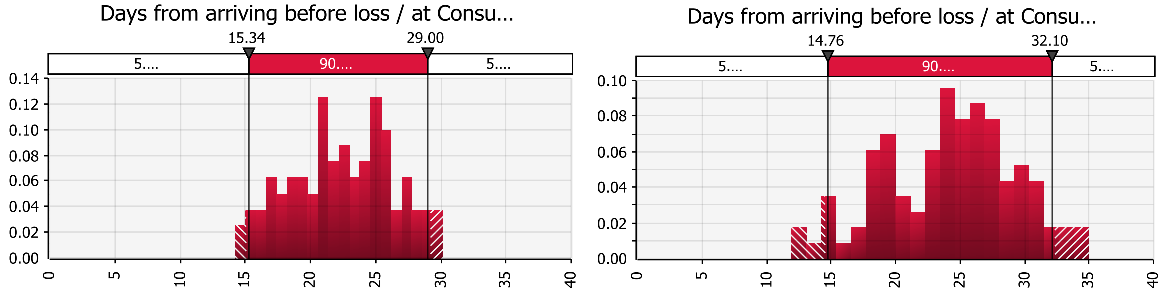
The @RISK software also provides a built-in function to show the most significant inputs determining any chosen output. Here we determine the key input values associated with the upper quartile (top 25%) of trade chain durations. Table 4.5.06 shows those input variables where the median associated with the upper quartile of the results differed most (i.e. at least half a standard deviation) from the overall median. As can be seen in Table 4.5.06, in Trade chain 1, the total trade chain duration was strongly dependent on the period the commodity spent at the consumer before disposal. Trade chain 2 was also dependent on the period at wholesale. Trade chains 3 and 4 showed a broader spectrum of dependency on the input variables including some of the transport stages. As with apple, this was because in these trade chains, the time spent at each stage was short, so the effects of transport time have more impact on the overall duration.

Final model as parameterised | **Maximum duration of all stages 25% longer**

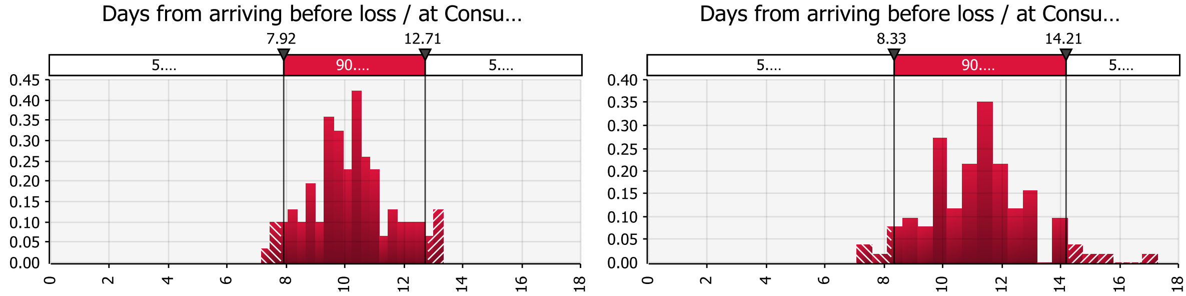
Trade chain 1 (Port to Retail to Consumer)



Trade chain 2 (Port to Wholesale/storage to Retail to Consumer)



Trade chain 3 (Port to Wholesaler/storage to Processor to Retailer to Consumer)



Trade chain 4 (Port to Processor to Retailer to Consumer)

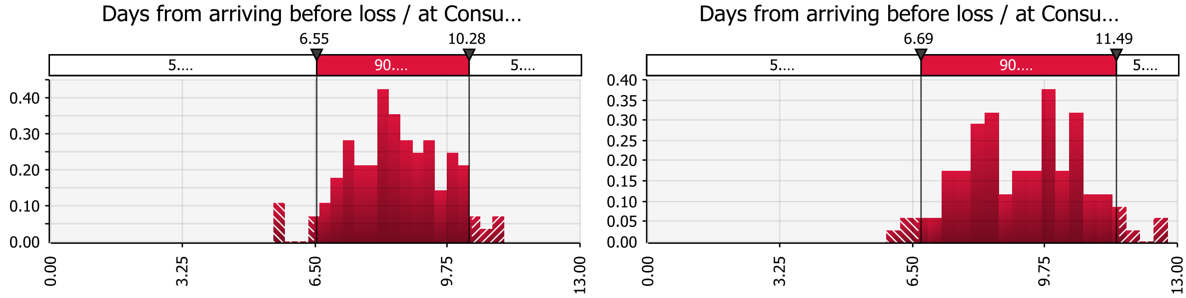


Figure 4.5.03: Sensitivity of the trade chain durations to a 25% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

Table 4.5.05: Summary of the change in risk period and the change in pest risk potential associated with a 25% increase in the maximum duration in all stages of the chain. The change in risk period calculated as the shift in the 95th percentile of the duration of the final stage of each trade chain (see Fig. 4.5.03; the change in pest risk potential is the sum of infested volume lost, corrected for infestation level at that stage, across all stages of the chain. The relative risk potential shows, per unit commodity on the trade chain, the percentage of the risk associated with each trade chain

Trade chain number	Change in risk period (95 %ile)	Change in pest risk potential	Relative risk potential	
			As paramterised	Stage durations + 25%
1	117%	94%	38%	38%
2	111%	93%	34%	33%
3	112%	97%	17%	18%
4	112%	99%	11%	11%

Table 4.5.06: Key inputs in the scenario where output is in the upper quartile (greater than 75%) of trade chain duration. Input percentiles are shown for each key input; this shows the strength of the association with simulations where the output values were highest, the higher the percentile the stronger the association

Trade chain number	Key inputs associated with long duration scenarios	Input percentiles
1	At consumer	87%
2	At consumer; At wholesaler and storage	85%; 71%
3	Transport to processor; At retailer; At airport; At processor	71%; 70%; 69%; 68%
4	Transport to retail; At retailer; At processor; At airport; At consumer	74%; 75%; 75%; 70%; 70%

4.5.4. Wheat model

Eight trade chains were identified as pathways of potential pest entry on wheat grain commodity. These eight trade chains involved different combinations of seventeen stages: at airport or harbour, in transport to wholesale, at wholesale and storage, in transport to mill, at mill, in transport to feed manufacturer, at feed manufacturer, in transport to farm, at farm storage, in transport to livestock, at livestock, in transport to food processor, at food processor, in transport to retailer, at retailer, in transport to consumer, and at consumer. In each case better evidence was available to support an estimate of mean duration of each of these stages than to estimate the variance. Lower limits could be estimated on the basis of the most rapid duration that was logistically practical, but the upper limits were uncertain.

As a result, the sensitivity analysis focussed on the effect of changes in the upper limits on the distribution of commodity durations along the trade chains. It is not possible to show all the results, but to summarise, the distribution of durations associated with the last stage of each of the eight trade chains is shown in Fig. 4.5.04. Two scenarios are shown for comparison: the results from the final model as parameterised, and where the upper limit of each stage was 50% longer than that estimated for the final model. A 50% increase was used in the case of the wheat model because it is a less perishable product than the fruit case studies, so there is more potential for the commodity to spend longer in each stage.

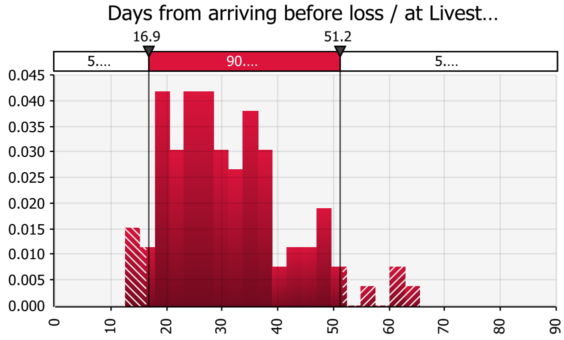
The increase in overall period that the commodity could occur at the final point of the trade chain was between 1.2 and 1.44-fold greater in the scenario where the maximum of each stage was increased by 50% (this being measured by the duration which encompassed 95% of the distribution, Fig. 4.5.04). The smallest increases were seen in Trade chains 8, 7 and 6 so these were less sensitive assumptions about maximum stage duration. The largest increases were seen in Trade chains 4, 2 and 8, so these were correspondingly more sensitive (Table 4.5.07).

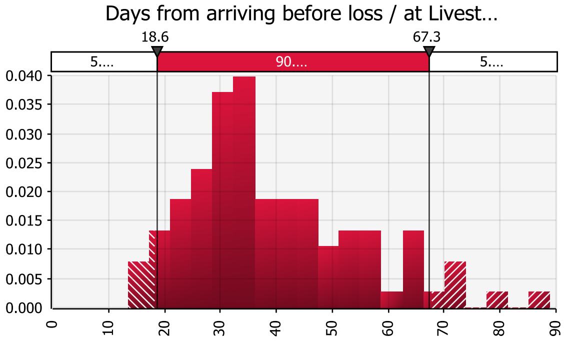
These increases in duration did not reflect a corresponding change in the potential for pest risk. The model incorporates pest mortality along the trade chain and as the time for the commodity to move through the trade chain increases this can lead to reduced infestation rates at later stages of the chain, depending on the biology of the pest concerned. If the later stages carry proportionately high risks of pest release, then an increase in duration can lead to lower risk as a whole. This was particularly true for Trade chain 3 (Table 4.5.07), where the highest risk was associated with the last stage in the chain, the point of feeding to livestock. Trade chain 1 reflected similar circumstances of higher risk at later stages. In the other trade chains, there was little impact of increased trade chain duration on potential pest risk. It was also Trade chains 1 and 3 that carried, per unit commodity, the highest relative risk potential for pest contact which could lead to introduction. An increase in all trade chain durations therefore had most impact in reducing risk on those trade chains that carried the highest risk. It is important to remember that these results are per unit commodity travelling along the trade chain so that the actual distribution of risk across all trade chains also depends upon the amounts associated with each trade chain.

The @RISK software also provides a built-in function to show the most significant inputs determining any chosen output. Here we determine the key inputs associated with the upper quartile (top 25%) of trade chain durations. Table 4.5.07 shows those input variables where the median associated with the upper quartile of the results differed most (i.e. at least ½ a standard deviation) from the overall median. As can be seen in Table 4.5.08, where some form of storage was involved in a trade chain this was usually the critical step, otherwise the critical step or steps were often associated with the various processing activities (milling, feed manufacture). It is of note that transport duration itself was never a critical variable.

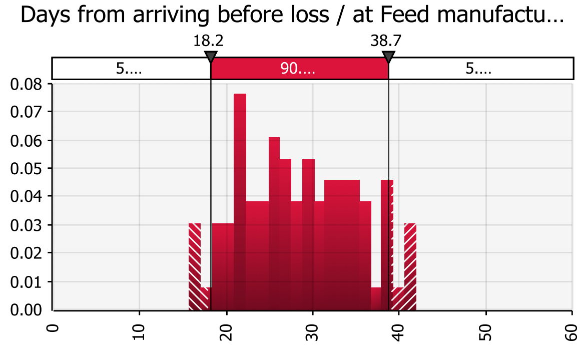
Final model as parameterised **Maximum duration of all stages 50% longer**

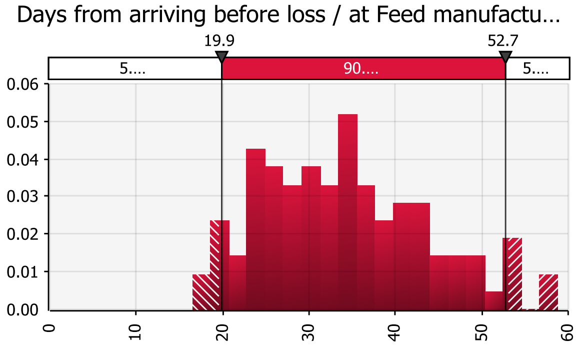
Trade chain 1 (Port to Mill, grain feed to Farm to Livestock)



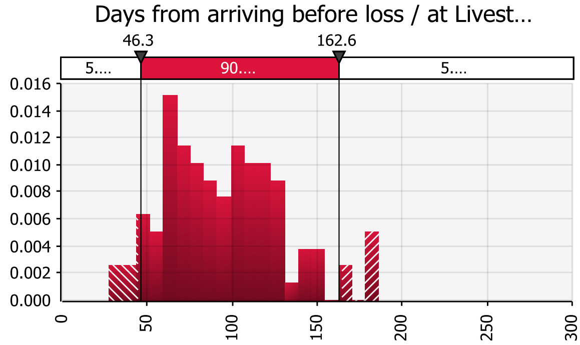


Trade chain 2 (Port to Mill; grain plus by-product to Feed manufacturer)





Trade chain 3 (Port to Storage to Mill, grain feed to Farm to Livestock)



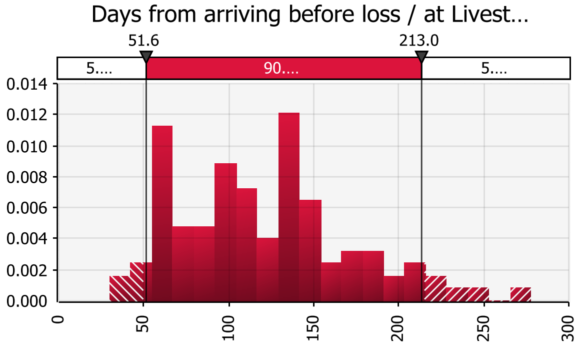
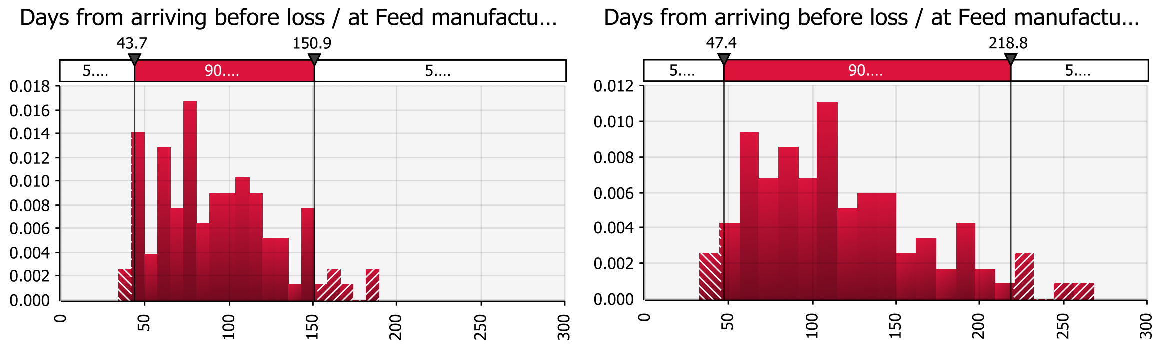


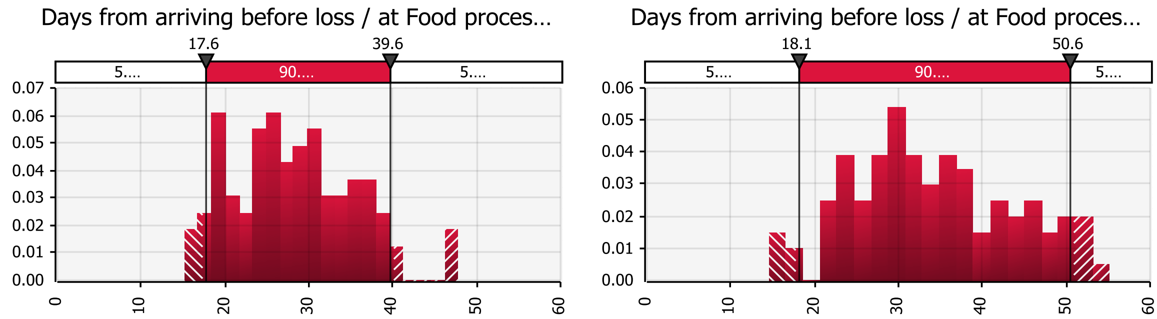
Figure 4.5.04: Sensitivity of the trade chain durations to a 50% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

Final model as parameterised **Maximum duration of all stages 50% longer**

Trade chain 4 (Port to Storage to Mill, grain plus by-product to Feed manufacturer)



Trade chain 5 (Port to Mill, flour and grain products to Food Processor)



Trade chain 6 (Port to Storage to Mill, flour and grain products to Food processor)

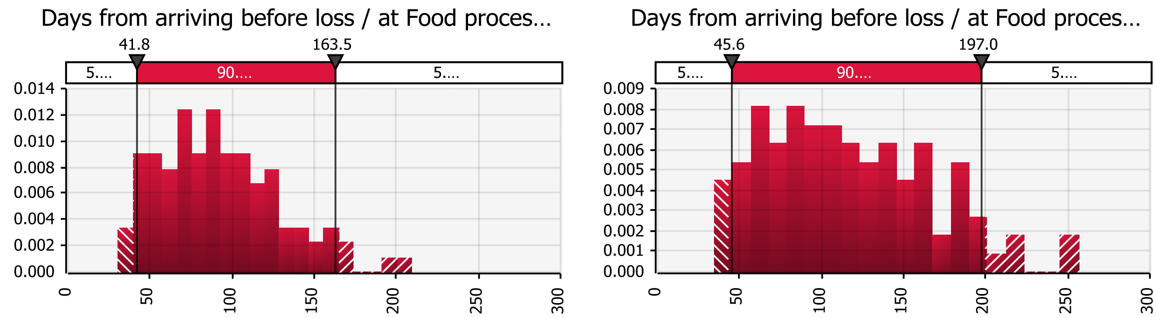
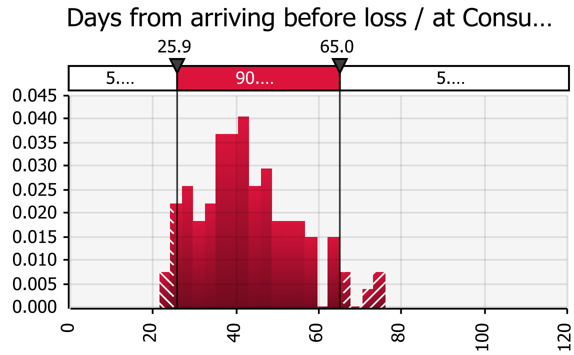
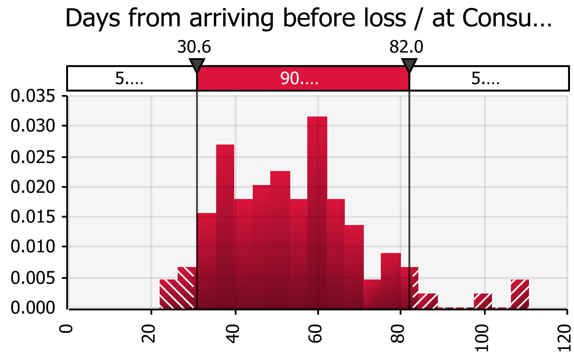


Figure 4.5.04: Sensitivity of the trade chain durations to a 50% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

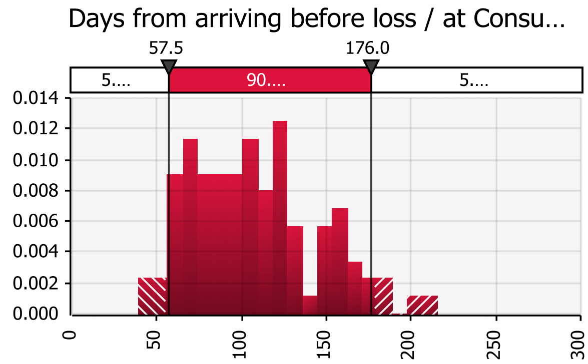
Final model as parameterised | **Maximum duration of all stages 50% longer**

Trade chain 7 (Port to Mill, flour products to Retail to Consumer)





Trade chain 8 (Port to Storage to Mill, flour products to Retail to Consumer)



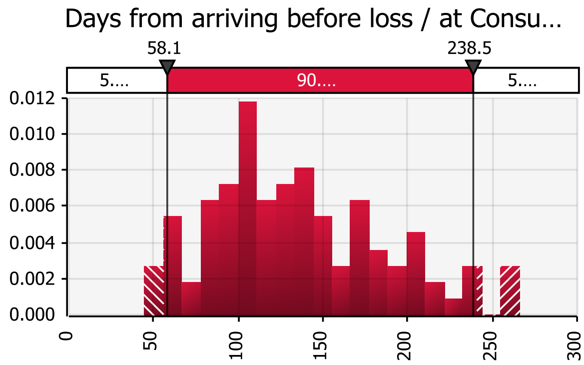


Figure 4.5.04: Sensitivity of the trade chain durations to a 50% increase in the maximum duration in all stages of the chain. Results are shown for all the commodity routes modelled

Table 4.5.07: Summary of the change in risk period and the change in pest risk potential associated with a 50% increase in the maximum duration in all stages of the chain. The change in risk period calculated as the shift in the 95th percentile of the duration of the final stage of each trade chain (see Fig. 3.2.4.1; the change in pest risk potential is the sum of infested volume lost, corrected for infestation level, across all stages of the chain. The relative risk potential shows, per unit commodity on the trade chain, the percentage of the risk associated with each trade chain

Trade chain number	Change in risk period (95 %ile)	Change in pest risk potential	Relative risk potential	
			As paramteri sed	Stage durations + 25%
1	131%	83%	56%	54%
2	136%	99%	4%	5%
3	131%	67%	15%	12%
4	145%	93%	5%	6%
5	128%	99%	4%	5%
6	120%	93%	5%	6%
7	126%	99%	4%	5%
8	136%	103%	5%	6%

Table 4.5.08: Key inputs in the scenario where output is in the upper quartile (greater than 75%) of trade chain duration. Input percentiles are shown for each key input; this shows the strength of association with simulations where the output values were highest, the higher the percentile the stronger the association

Trade chain number	Key inputs associated with long duration scenarios	Input percentiles
1	At farm storage	87%
2	At mill; At feed manufacturer	83%; 75%
3	At wholesaler and storage	87%
4	At wholesaler and storage	87%
5	At mill; At food processor	82%; 72%
6	At wholesaler and storage	87%
7	At consumer; At mill; At retailer	85%; 77%; 67%
8	At wholesaler and storage	87%

4.6. Comparison of models

4.6.1. General models

The four case studies using the models revealed some interesting differences in the patterns of risk across EU Member States. In the summaries presented in this section for model comparison, two sets of figures are shown. Figures 4.6.01 to 4.6.04 show the percentages of EU imports of the pest-infested commodity entering each EU Member State over the period of the study, 2010 to 2014. The import percentages include the net transhipments of infested commodity between Member States. The second set of figures, Figures 4.6.05 to 4.6.08 show the NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by the pest (km^2). To show the relative risk associated with different types of use, the contact risk is disaggregated into that associated with the retail trade chains and that associated with processing trade chains. Contact risk therefore depends upon both imports and presence of hosts in the Member State, so for example, there are large imports of infested sweet orange into the Netherlands but the contact risk is negligible because there is no commercial production.

In the orange pest case study, more than 50% of the total infested imports entered two states, Spain and the Netherlands, and the top eight importers represented about 90% of all imports (Fig. 4.6.01). Of these, Spain, Italy and Portugal, and to a lesser extent, France, offered the greatest opportunity for pest contact. This was reflected in the detailed analysis of contact risk by NUTS2 region and month of the year. Of the 30 most risky region-month combinations, 24 were in Spain, 4 in Italy and 2 in Portugal (Fig. 4.6.05).

For Spain only, highly commodity specific information was available about the locations of orange processors and risk associated processing use was therefore associated only with those NUTS2 regions specifically identified to contain orange processors. Of these, Andalucía, Valencia and Murcia featured with some significant risk associated with processing. It is also evident that risk associated with processing uses is very small compared to retail uses. This is because comparatively expensive imported commodity is used mainly for higher value retail uses. In countries other than Spain, the locations of processors were determined by the distribution of fruit and vegetable processing enterprises in general and very small risk associated with processing risk was identified in Lombardia, Italy and Lisboa, Portugal.

In the apple pest case study, nearly 90% of the total infested imports were to the UK with most of the remainder in Finland, Sweden, Ireland, Spain and Netherlands. The source countries of the pest were limited to US and Canada and the export patterns of these countries explains the much more focussed fate of infested commodity in a particular EU state than was the case with orange (Fig. 4.6.02). However, within the UK, the risk was widely spread across many locations, reflecting both the wide distribution of apple production and food processing. As a percentage of total imported apple use, apple processing use was a more significant component of risk than was the case for orange. All of the top 30 most risky region-month combinations occurred in the UK (Fig. 4.6.06). The most risky non-UK region was ranked 87th and was Lietuva (Lithuania), in July, which was associated with 0.3% of the total EU risk.

In the plum pest case study, the sources of the pest were also restricted to US and Canada but, reflecting the import patterns, the risk showed a wider distribution between Member States with UK, Belgium, France, Netherlands and Germany together associated with about 95% of the infested imports to the EU (Fig. 4.6.03). The UK represented about two-thirds of the total infested imports. Within Member States, the risk was very highly localised compared to the apple case study with about one-third of all EU risk occurring in one NUTS2 region in one month, Kent (UK) in August (Fig. 4.6.07). The top 5 region and month combinations represented nearly 60% of all risk. All were in the UK. Although the risk distribution curve declines steeply (Fig. 4.6.07), within the top 30, the risk was also widely distributed in Germany (14 of top 30) and also present in France (two of top 30). Processing of imported plums was a very minor use and this was reflected in the proportion of risk associated with processing (Fig. 4.6.07).

In the wheat pest case study, the sources of the pest were various countries in South America and Australasia. Italy and Spain together accounted for about 90% of the entry of potentially infested imports, with Germany and Portugal, and to a lesser extent Romania, Netherlands and the UK, accounting for the remainder (Fig. 4.6.04). Within the importing countries the risk was widely distributed between NUTS2 regions; there were similarities with the apple case study in this respect. Of the 30 most risky region and month combinations, there were 19 in Italy, eight in Spain, and three in Netherlands, Zuid Holland in particular (Fig. 4.6.08). The latter was associated particularly with the port of entry, Rotterdam. The overall pattern of risk also reflected other major ports of entry, e.g Hamburg and Liverpool. Risk associated with milling uses dominated which reflected the dominant commodity use. The distribution amongst NUTS2 regions was based on the number of milling enterprises. The location of Industrial uses was based on the locations of biofuel enterprises attributed to NUTS2 region categorized under NACE code 20.14, which includes fermentation of sugarcane, corn or similar to produce alcohol and esters. The pattern of risk associated with industrial uses was widespread across NUTS2 regions, to a degree appearing to be correlated with milling risks but not in every case. For example risk associated with industrial used was very low in Sicilia, Castilla y Lion and Castilla la Mancha (Fig. 4.6.08).

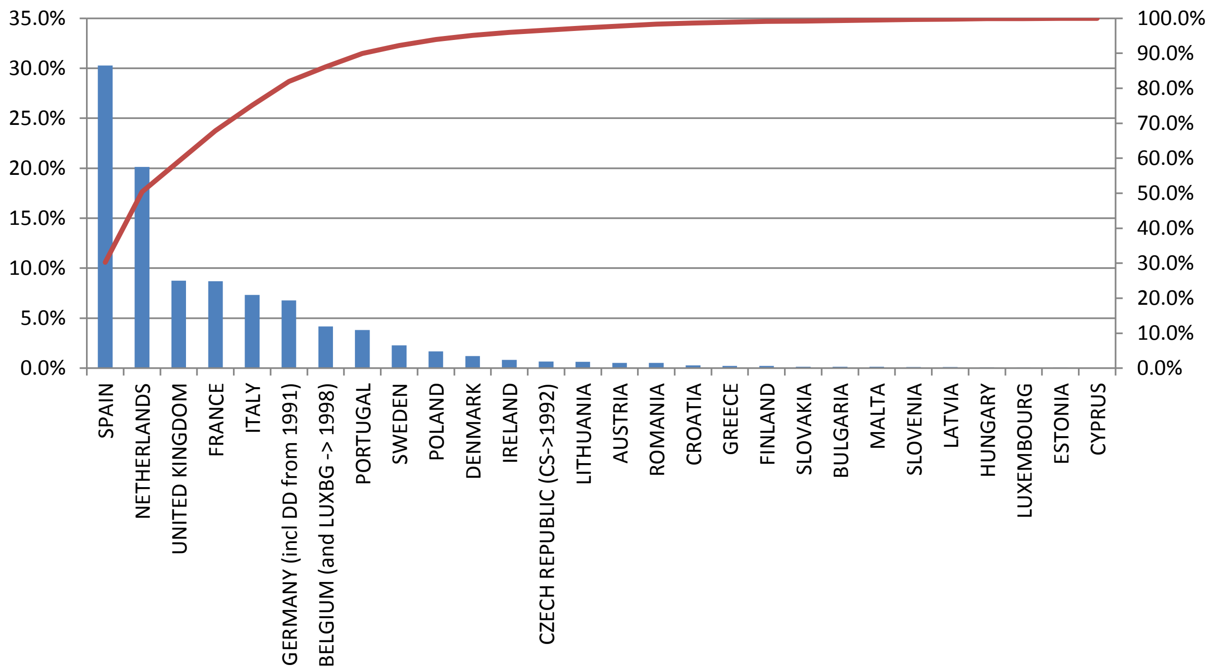


Figure 4.6.01: The percentages of EU imports and net transhipments of pest-infested sweet orange entering each EU Member State over the period 2010 to 2014. Member States are shown in rank order (histogram) and the cumulative percentage is also indicated (red line)

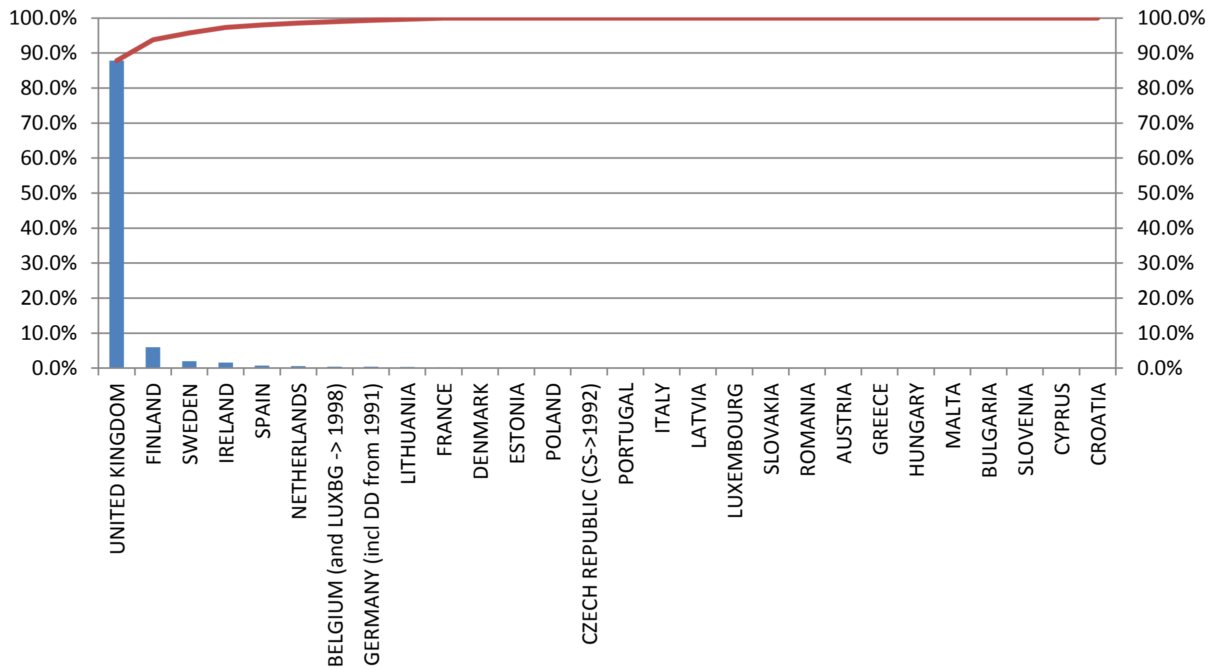


Figure 4.6.02: The percentages of EU imports and net transhipments of pest-infested desert apple entering each EU Member State over the period 2010 to 2014. Member States are shown in rank order (histogram) and the cumulative percentage is also indicated (red line)

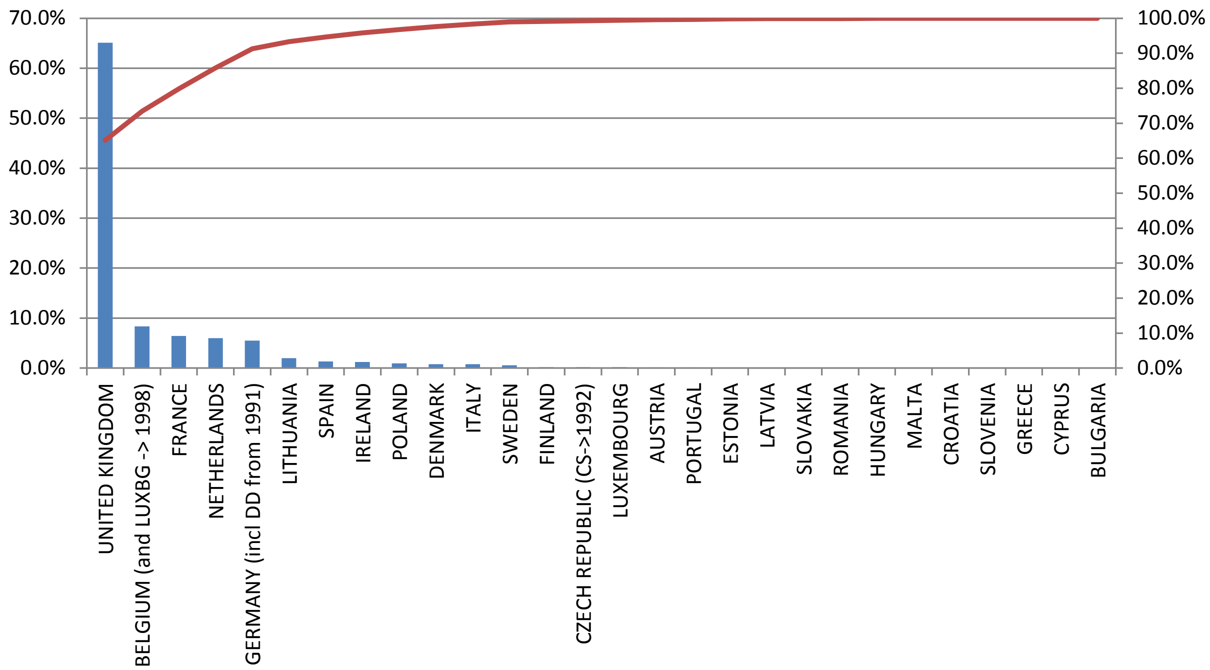


Figure 4.6.03: The percentages of EU imports and net transhipments of pest-infested plum entering each EU Member State over the period 2010 to 2014. Member States are shown in rank order (histogram) and the cumulative percentage is also indicated (red line)

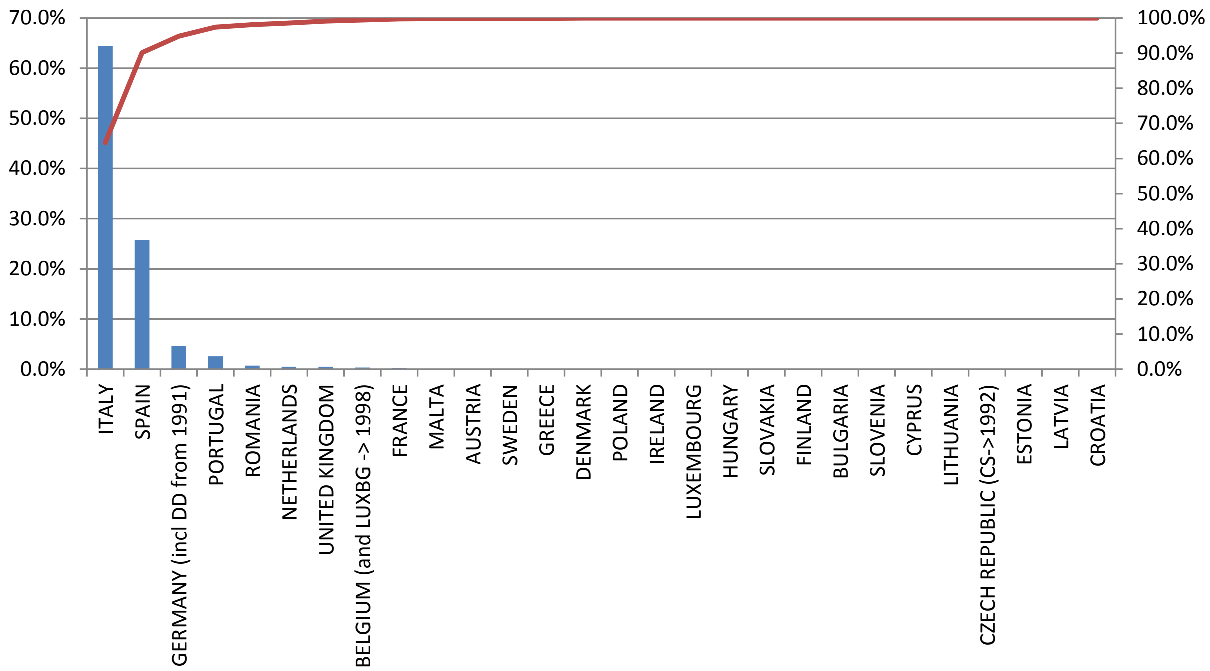


Figure 4.6.04: The percentages of EU imports and net transhipments of pest-infested wheat entering each EU Member State over the period 2010 to 2014. Member States are shown in rank order (histogram) and the cumulative percentage is also indicated (red line)

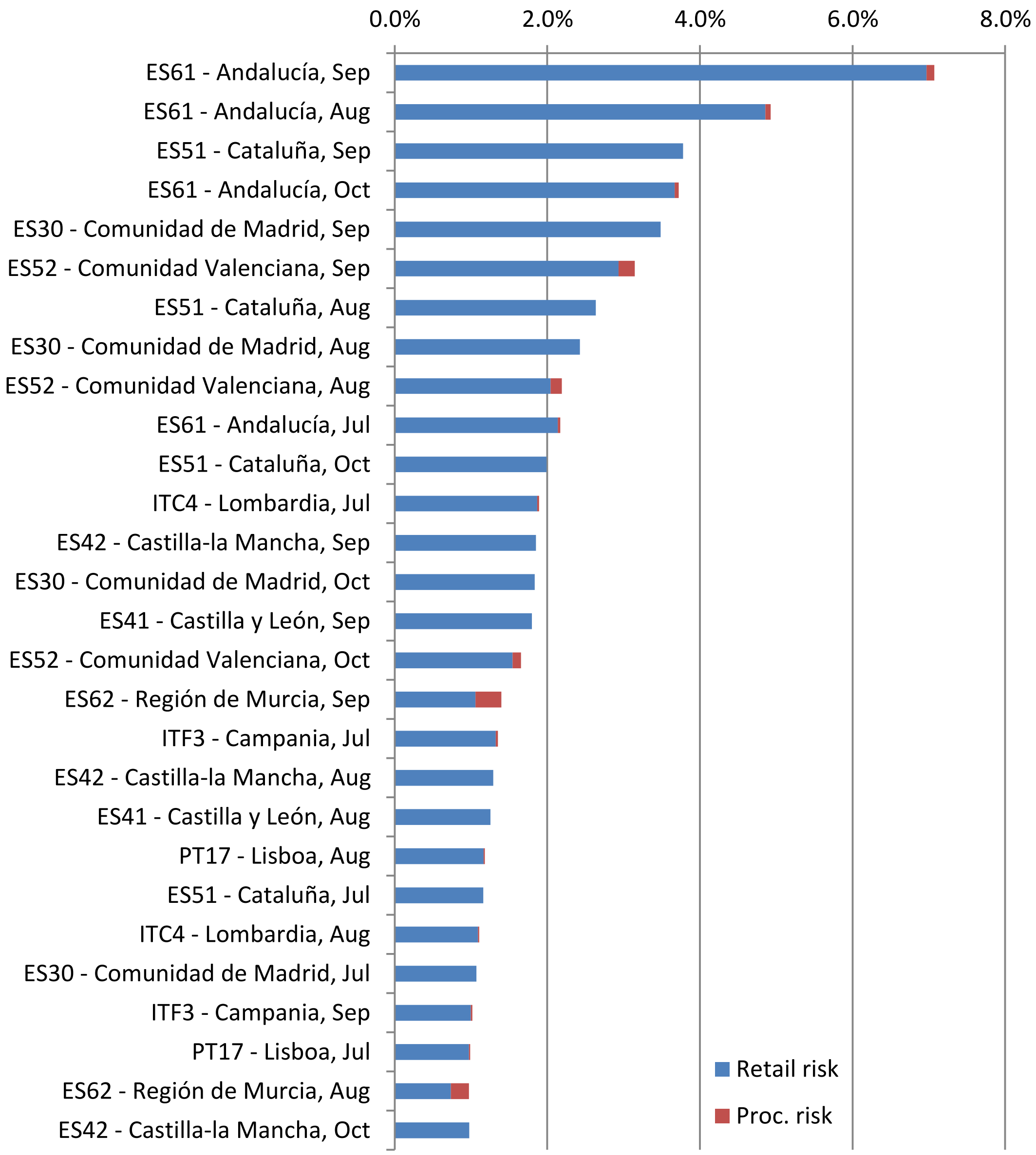


Figure 4.6.05: The percentage of the total EU risk falling in particular EU regions and months. In rank order based on five-year average trade, the top 30 NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by pest (km^2). The contact risk is disaggregated into that associated with retail use and that associated with processing use of imported sweet orange

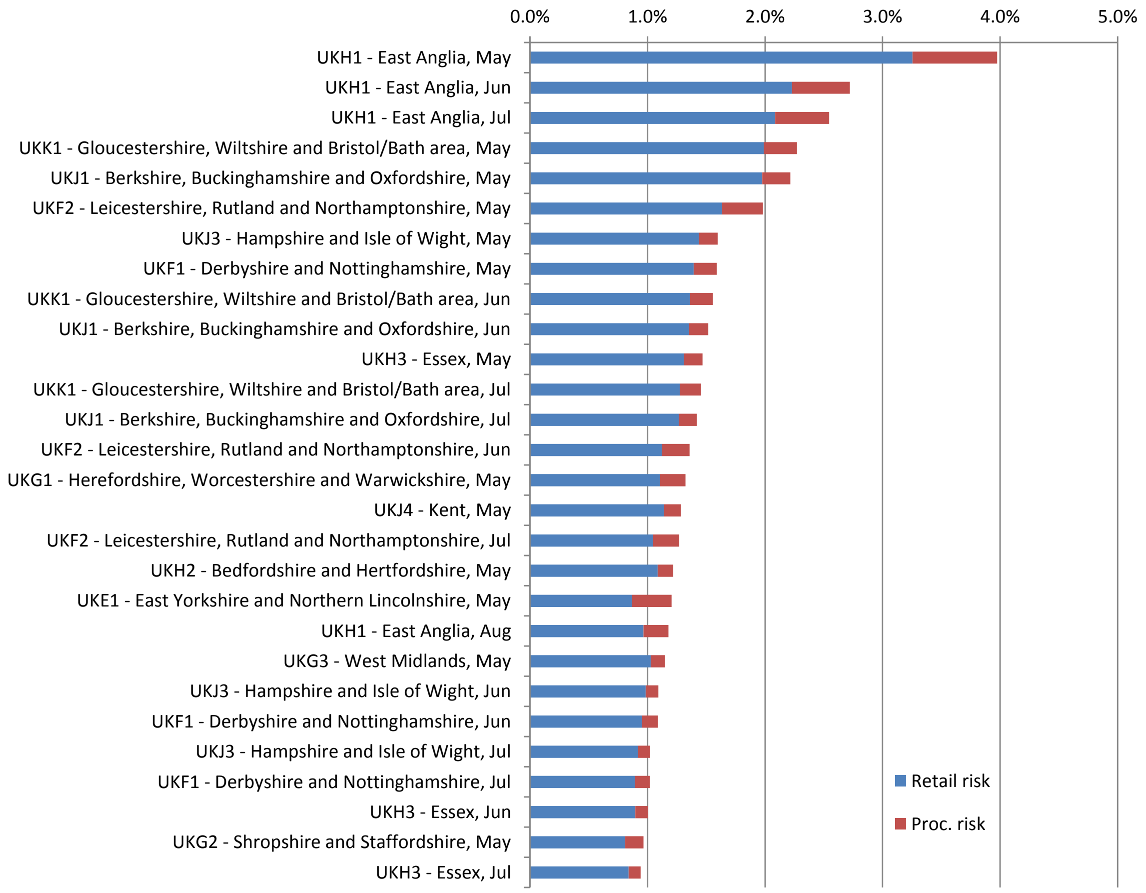


Figure 4.6.06: The percentage of the total EU risk falling in particular EU regions and months. In rank order based on five-year average trade, the top 30 NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by pest (km^2). The contact risk is disaggregated into that associated with retail use and that associated with processing use of imported apple

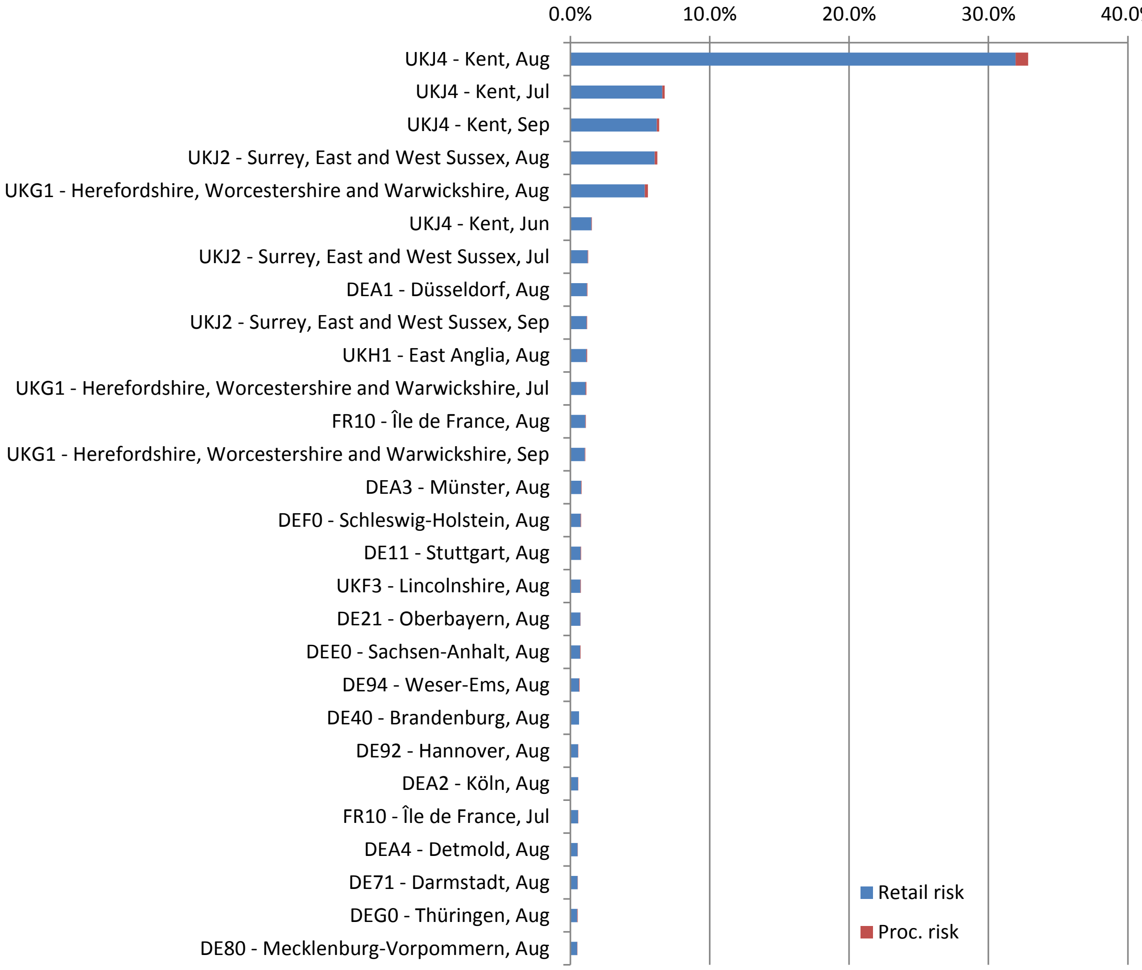


Figure 4.6.07: The percentage of the total EU risk falling in particular EU regions and months. In rank order based on five-year average trade, the top 30 NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by pest (km^2). The contact risk is disaggregated into that associated with retail use and that associated with processing use of imported plum

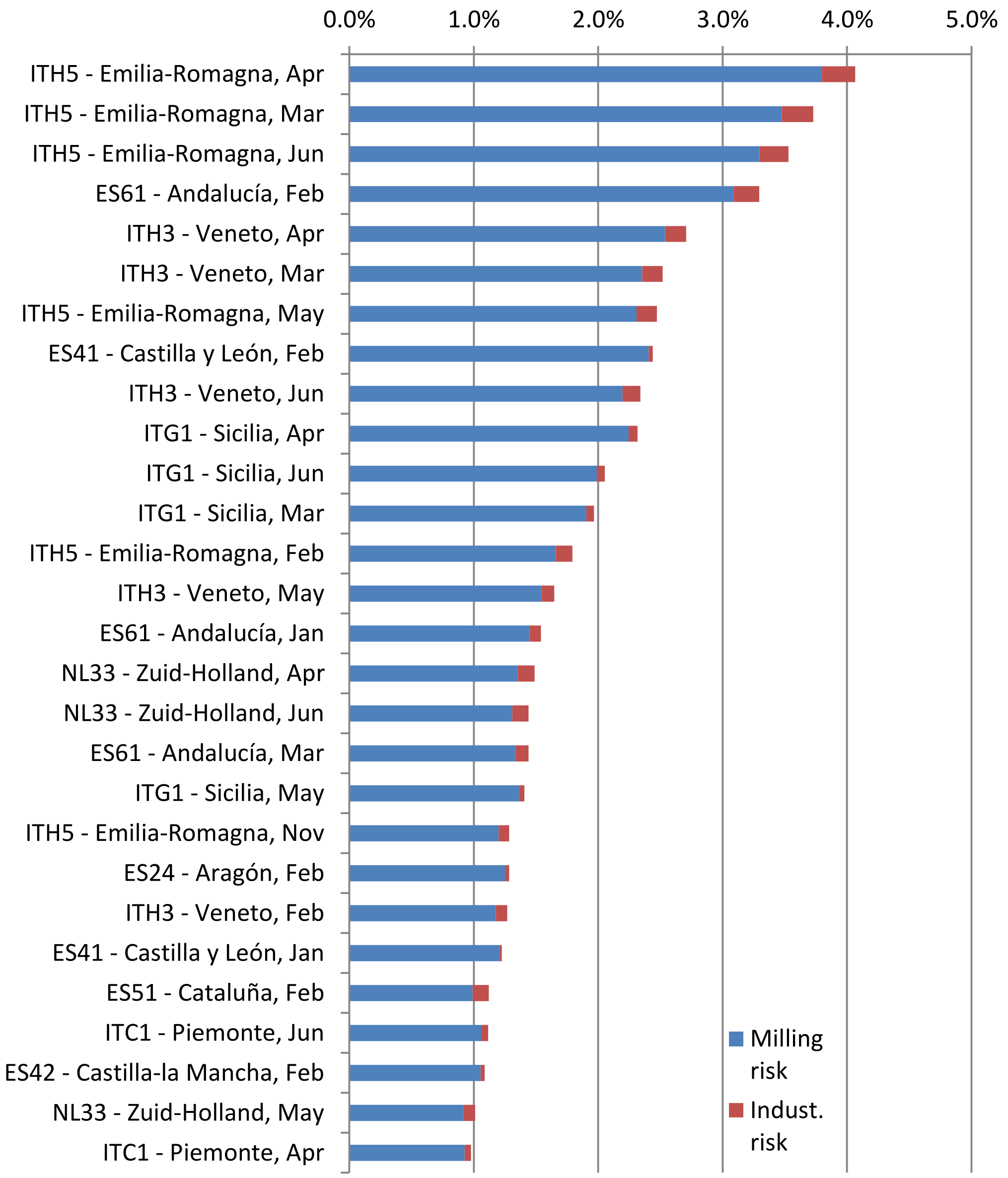


Figure 4.6.08: The percentage of the total EU risk falling in particular EU regions and months. In rank order based on five-year average trade, the top 30 NUTS2 regions and months having greatest risk of pest contact which could lead to establishment. This is calculated as the product of the volume of the infested material volume arriving (100 kg units) and vulnerable area accessible by pest (km^2). The contact risk is disaggregated into that associated with milling use and that associated with industrial use of imported wheat

4.6.2. Consignment models

The models of the three fruit commodities were developed to share a common structure which has the potential to be employed for other similar risk analysis objectives relating to fruit pests. In these models, four possible routes for trade chains were identified associated with the use of fresh fruit imports to EU Member States:

- Trade chain 1 (Port/Airport to Retail to Consumer)
- Trade chain 2 (Port/Airport to Wholesale/storage to Retail to Consumer)
- Trade chain 3 (Port/Airport to Wholesaler/storage to Processor to Retailer to Consumer)
- Trade chain 4 (Port/Airport to Processor to Retailer to Consumer)

Analysis of the models revealed commonalities and differences between the three fruit pest case studies. Trade chain durations were of broadly similar length for the three fruit models with plum traveling through the chains slightly more quickly because of its more perishable nature compared to the other fruits. For all three fruits the duration of the risk period (at the final stage of the trade chains) was long, being up to about two weeks, depending on the specific trade chain (Table 4.6.09). For all the fruit models, Trade chains 1 and 2 where about twice the duration of Trade chains 3 and 4. This was because retail and consumption of whole fresh product has a longer time frame than that of processed product such as fruit pieces.

Due to their inherent features, some chains were more likely to result in pest release than others and Trade chains 1 and 2, associated with fresh produce, carried higher risk for all fruits. It is interesting to note that in the case of plum, risk was spread more evenly across all trade chains (Table 4.6.10). For orange, risk was very low for Trade chain 4. This table concerns potential risk as a property of the trade chain. The actual distribution of risk also depends on the distribution of commodity use as discussed in the general model.

By identifying the values of the various inputs in those simulations which result in high (long duration) values, it is possible to identify those inputs which are most influential in causing long duration situations. In Table 4.2.3, the influential inputs for the three fruit models are compared for each trade chain in turn. For all fruits, the duration or Trade chain 1 was heavily influenced by the time the fruit spends at the consumer before any waste occurs. Trade chain 2 was also influenced strongly by the period at the consumer and also by the period spent at the wholesaler; apple in particular was associated with period at the retailer. The durations of Trade chains 3 and 4 had a more complicated dependency for all fruits and notably the period spent at the airport after arrival was consistently influential. The period of transportation to retail was also consistently influential in Trade chain 4. The more complicated dependency in Trade chains 3 and 4 was caused by the rapid throughput of these chains which made the otherwise relatively rapid stages such as transport a more significant part of the whole period.

The colour-shaded cells in Table 4.6.11 show the row and column frequencies of the influential inputs. Over all the trade chains, the best way to speed up the movement of commodity, and therefore reduce the period of pest exposure would be, in order of importance, to reduce time spent at the consumer, at the airport and at the retailer and at the processor (if appropriate). However, if we consider that Trade chains 1 and 2 had consistently higher inherent risk, and that fresh use has much higher volume than processed (see general models) then it is the periods at the consumer and at the wholesaler (if appropriate) which are the overwhelmingly critical steps.

Table. 4.6.09: Comparison of trade chain durations (days from arrival) in the three fruit final models as parameterised, showing the start and ends times of the bulk of the distribution (from the 5th to 95th percentiles) and the period between them

Trade chain	5th percentile			95th percentile			Interval		
	Orange	Apple	Plum	Orange	Apple	Plum	Orange	Apple	Plum
1	12.3	12.7	11.0	25.9	24.9	23.9	13.7	12.3	12.9
2	16.8	17.0	15.3	31.6	31.5	29.0	14.8	14.5	13.7
3	9.4	9.3	7.9	15.7	16.0	12.7	6.3	6.7	4.8
4	7.7	8.0	6.6	13.7	13.4	10.3	6.0	5.4	3.7

Table 4.6.10: Comparison between the three fruit models of the relative pest risk potential associated with each trade chain, per unit commodity on the trade chain

Trade chain	Relative risk potential		
	Orange	Apple	Plum
1	51%	54%	38%
2	43%	38%	34%
3	6%	5%	17%
4	0.1%	3%	11%

Table 4.6.11: Comparison of the three fruit models, orange (Or.), apple (Ap.) and plum (Pl.) showing at which points in the trade chains the key inputs associated with long trade chain durations occur. The input percentiles are shown for each key input; this shows the strength of the association with high (above 75th percentile) output values; the higher the percentile the stronger the association

Stage in trade chain	Trade chain 1			Trade chain 2			Trade chain 3			Trade chain 4			Total cases
	Or.	Ap.	Pl.	Or.	Ap.	Pl.	Or.	Ap.	Pl.	Or.	Ap.	Pl.	
on arrival													0
at Airport or harbour							76	78	69	79	80	70	6
in Transport to wholesale							68						1
at wholesale and storage				76	76	71							3
in Transport to processor									71		69		2
at Processor								73	68	81		75	4
in Transport to retail										68	74	74	3
at Retail					78		67		70			75	4
in Transport to consumer													0
at Consumer	86	85	87	81	80	85		70		69		70	9
Total cases	1	1	1	2	3	2	3	3	4	4	3	5	

The wheat model was more complex reflecting the uses of this imported commodity. The wheat model has the potential to be employed for other similar risk analysis objectives relating to grain pests. In this model, eight possible routes for trade chains were identified associated with the use of wheat grain imports to EU Member States:

- Trade chain 1 (Port to Mill, grain feed to Farm to Livestock)
- Trade chain 2 (Port to Mill; grain plus by-product to Feed manufacturer)
- Trade chain 3 (Port to Storage to Mill, grain feed to Farm to Livestock)
- Trade chain 4 (Port to Storage to Mill, grain plus by-product to Feed manufacturer)
- Trade chain 5 (Port to Mill, flour and grain products to Food Processor)
- Trade chain 6 (Port to Storage to Mill, flour and grain products to Food processor)
- Trade chain 7 (Port to Mill, flour products to Retail to Consumer)
- Trade chain 8 (Port to Storage to Mill, flour products to Retail to Consumer)

Analysis of the model revealed differences in the pest risk implications of the eight trade chains. Trade chain durations clustered into two groups depending upon whether a storage stage was present in the chain. When no storage stage was present the distribution of trade chain durations was from 16 and 65 days, with an associated risk period of about three to five weeks, depending on the specific chain (Table 4.6.12). When a storage stage was present the duration was between 44 and 167 days with an associated risk period of about 3.5 to 4 months.

Due to their inherent features, some chains were more likely to result in pest release than others and Trade chain 1 and to a lesser extent Trade chain 3 were the most inherently risky chains, being associated with the feeding of whole grain feed to livestock. The lower risk associated with Trade chain 3 was due to pest mortality during the period of storage prior to feeding (Table 4.6.12).

By identifying the values of the various inputs in those simulations which result in high (long duration) values, it is possible to identify those inputs which are most influential in causing long duration situations. In Table 4.6.12, the influential inputs for the wheat model are compared for each trade chain. For those trade chains which involved a period of storage, there was a dominant influence of the period spent in wholesale or storage because this was much longer than any of the other stages. For the non-storage trade chains the period at the mill was a key influence in three of the four chains. Other key influences were related to the specific of particular chains.

The colour-shaded cells in Table 4.6.13 show the row and column frequencies of the influential inputs. Over all the trade chains, the best way to speed up the movement of commodity, and thereby reduce the period of pest exposure would, in order of importance, be to reduce time spent at the wholesaler/storage and at the mill. However, if we consider that Trade chains 1 and 3 had consistently higher inherent risk, then at farm storage is also a critical step.

Table. 4.6.12: Comparison of trade chain durations (days from arrival) in the wheat model as parameterised, showing the start and ends times of the bulk of the distribution (from the 5th to 95th percentiles) and the period between them, and comparison of the relative pest risk potential associated with each trade chain, per unit commodity on the trade chain

Trade chain	5th percentile	95th percentile	Interval
1	16.9	51.2	34.3
2	18.2	38.7	20.5
3	46.3	162.6	116.3
4	43.7	150.9	107.2
5	17.6	39.6	22.0
6	41.8	163.5	121.7
7	25.9	65.0	39.1
8	57.5	176.0	118.5

Trade chain	Relative risk potential
1	56%
2	4%
3	15%
4	5%
5	4%
6	5%
7	4%
8	5%

Table 4.6.13: Comparison of the three fruit models, orange (Or.), apple (Ap.) and plum (Pl.) showing at which points in the trade chains the key inputs associated with long trade chain durations occur. The input percentiles are shown for each key input; this shows the strength of the association with high (above 75th percentile) output values; the higher the percentile the stronger the association

Stage in trade chain	Trade chain								Total cases
	1	2	3	4	5	6	7	8	
on arrival									0
at Airport or harbour									0
in Transport to wholesale									0
at wholesale and storage			87	87		87		87	4
in Transport to mill									0
at Mill		83			82		77		3
in Transport to feed manufacturer									0
at Feed manufacturer		75							1
in Transport to farm									0
at Farm storage	87								1
in Transport to livestock									0
at Livestock									0
in Transport to food processor									0
at Food processor					72				1
in Transport to retailer									0
at Retailer							67		1
in Transport to consumer									0
at Consumer							85		1
Total cases	1	2	1	1	2	1	3	1	

5. Research Needs

Infestation levels of imports, especially differences between source countries and in relation to the time of year when the exports occur is an important driver in all the models. Sensitivity analysis showed examples of how risk patterns change when different source countries exhibit differing infestation rates. The issue is not just the infestation rate expressed as a percentage of commodity units but the numbers of pests per unit volume of commodity. Because the levels of infestation are extremely low in most cases, it is unlikely to be possible in most circumstances to obtain good estimates from interception records. Indeed for three of the case studies in the project, no interception records were available.

Information was available about the proportions of the commodities going to different uses and this is given in detail in the Appendices 1-4. It was possible to obtain general figures in most case as well as a few country-specific estimates. The main division is between processing uses and retail uses and further research could help to establish more accurately differences between Member States and differences related whether fruit is locally produced or imported. Research to obtain more country-specific estimates would improve the partitioning of risk spatially within Member States because distributions associated with retail and processing uses differ. Similar issues apply to the different uses of grains for milling, animal feed and other uses.

The location of processing activity within Member States also has an important impact. The spatial scale of the model was the NUTS2 region and with the exception of orange processing in Spain, where commodity specific data were available, the location of commodity processors for all the fruit commodities was based on the numbers of general vegetable and fruit processors in each NUTS2 region. The pattern of processing of specific fruit commodities is expected to have commodity specific variation within this general pattern of processing enterprise distribution. Research to find out the distributions of processing with respect to specific fruit of interest would increase the accuracy of the within-country distribution of risk associated with processing uses.

Estimates of pest survival were relatively easy to obtain but the data did not always reflect the conditions pertaining to the commodity or its handling and processing. In many cases the processes to which fruit are subjected are certain to cause mortality. There are however some processes which allow some level of pest survival. Better understanding is required of pest survival in such cases where some survival is possible.

The models consider potential contact through the coincidence of the destinations of infested commodity and the locations of hosts of the pest and a suitable time of year and host growth stage. The capacity of the pest to transfer in such circumstances was inferred from its general dispersal ability in relation to the probability of host encounter. This final transfer stage of pest entry is critical and very uncertain.

Particularly in relation to the assessment of time scales of risk using the consignment models, further research to determine more accurately the periods of the various stages of the trade chains would help to reduce the variability expressed in the results. Little information was available, but as a general principle it is known that the industry tries to move a commodity through the chain as quickly as practicable. Such research would require more practical work in collaboration with industry to establish the detailed timescales of the various commodity pathways.

As a general issue, estimates of means or modes of parameters could often be estimated with reasonable confidence but variability was largely unreported. Lack of information about variance does not in general affect the rank in the assessment of relative risk because this depends on the means, or ranking of means. However, the degree to which outcomes overlap is dependent on knowledge of variance and this is important if a more detailed understanding of the pattern of risk is required, e.g. how likely is the risk to exceed a certain threshold. It would be useful to carry out further work to classify in detail which management responses to risk rely on a relative estimate of risk or risk ranking, which on an absolute measure of mean risk as a true probability, and which rely on variability in risk.

6. Conclusions

6.1. Potential to build quantitative pathway models

The focus of the work in QPAFood was on three fruit commodities and one grain commodity, each with a selected pest which posed an import risk to the European Union. For this series of four case studies, two types of quantitative pathway model have been developed: general and consignment. Both allow analysis of aspects of risk associated with the entry of alien pest species to Member States of the European Union. The general models focus on the geographical distribution of pest entry across the EU and the consignment models focus on the timing of events along the commodity trade chains that may lead to entry. The models make use of diverse information available about commodity trade, production and use, and about pest infestation of imports, host needs, dispersal and pest biology. The detail and accuracy with which quantitative estimates could be made varied widely in the different parts of the models. Each of the models has potential to describe a range of pathway routes, but are specified for only one pest organism at a time. Despite the limitation imposed by lack of or poor quantitative information, the models have led to new insights in a way that is not possible through the use of qualitative models which employ ordinal linguistically-defined ratings to describe risk.

6.1.1. Data limitations that limit quantification

The models have been prepared in as generic a way as possible. This has the advantage of producing a consistent form of analysis with comparable interpretation across cases. However, it means that the models are relatively large and contain streams of calculation that are redundant for specific pathways. The models have been constructed so that only data relevant to specific pathways need to be entered.

Trade data are available on a monthly basis for major food commodities, but data on minor commodities are generally aggregated. Furthermore, within the generality of a commodity trade there may be highly specific trade networks that are atypical of the overall trade pattern, for instance for commodities of interest to particular communities or for consumption at a specific season. Domestic production data is generally only available on an annual basis. Infestation data is generally not available, and interception data is variable depending on effort and reporting. Estimates of potential distributions of infestation within commercial quality specifications give some quantification of pest infestation proportion, but not pest numbers. Use streams are variable according to market demands and opportunities. Retail consumption can be broadly estimated based on human populations within regions, and livestock feed use can be based on livestock numbers, but this assumes consumption patterns are similar across regions. The presence of businesses involved in processing fruit and vegetables is recorded on a regional basis, but is not specified according to type of product or type of processing; also some processing is carried out by mobile processing units mounted on lorries, so that they can move seasonally. The seasonality of processing activities is not recorded or available centrally. Domestic production and area data for crops is available, but non-crop host area and availability are not as readily available. Biological information on natural dispersal is often available, but there is no clear evidence on the number of dispersal kernels to expect.

The model was built using @RISK in order to incorporate the different forms of uncertainty directly in the calculations. Incorporating variance in parameter values led to outcomes in which the distribution of risk was typically strongly skewed to a high probability of low risk but with a long tail indicating a small probability of higher risks. Throughout the work, it proved very difficult to estimate parameter variance, as typically, the information that was obtainable to estimate parameters was based on a single value. Whilst the variance of outcomes provided an extra dimension to the perception of risk, the overall patterns of risk between uses and regions are unaffected by this variance. It is often the primary statistics (means) rather than the secondary statistics (variance) that are most needed in order to make decisions to improve risk management, e.g. allocation of resources at locations and times of (average) high risk. Apart from the poor estimates of variance, the general models also have a very large number of parameters, and together this made analysis of the most important sources of variance intractable. The simpler representation of the consignment models did allow identification of steps in the trade chain where value uncertainty was most influential on the final result. This was described in the sensitivity analysis.

6.1.2. Intrinsic limitations to quantification

Trade volume is a key driver for potential distribution of exotic pest organisms. The data demonstrates substantial variability in trade patterns between and within years. Pest risks associated with new trade are particularly difficult to assess, as there is no history of volumes or distribution routes on which to base estimates. New trade also has no history of interceptions that might inform pest infestation estimates. The models can be used with projected volumes and routes, but trade patterns are difficult to predict with accuracy. Trade in fruit commodities is based on markets that generally have a high commercial quality standard with rapid transportation and handling to get them to consumers in good condition with minimal waste. This implicitly means that quantitative estimates of distributions are highly skewed to low presence of infestation and are difficult to validate through practical inspection regimes.

The analysis in these models has demonstrated the importance of scale in both time and space. The risk at an annual and national level can be very different from specific monthly risks at a regional level. It is likely that risks may also be different if they could be modelled at weekly and local levels. Probabilistic distributions are made up of sets of very specific events determined by their immediate circumstances, which may be different from the average conditions. Quantitative pathway analysis may serve a useful purpose in highlighting the conditions under which risks are greatest, so that appropriate action can be taken. Relative and subjective values may be sufficient to focus management in many cases, even where absolute data are limited.

In many cases the very low levels of pest infestation in imported commodities make detection very unlikely with any practicable phytosanitary procedures so there is no direct basis to calculate infestation rate in the imported commodity. In the QPAFood project inferences were made using any information about infestation at the place of production and assumptions about survival in transit. In the sensitivity analysis it was shown that differences in infestation between source countries can cause large differences in the risk profile across Member States, due to differences in both the infestations and trade patterns.

Another aspect of the pest on the pathway which defies measurement is the release and movement of the pest from the commodity and its waste. Estimates of whether any pests present are likely to survive in the commodity or its waste to potential release points is possible but in most cases there is unlikely to be any basis to estimate the probability of whether a surviving pest actually establishes on a host in the country in which it arrives. Even if a pest organism has been found on hosts in a destination country, these events are too few to establish any relationship between these and pest transfer probability.

6.1.3. Value of quantitative models in pathway analysis

The general models proceed as a sequence of steps with outputs available at different stages. The initial part deals with the distribution of pest infestations through trade and the dilution effects of local production. Accurate and detailed data on import volumes and domestic production are available so it is possible to make good quantitative predictions with respect to trade volumes entering and moving between Member States. The infestation levels of the imports were much more uncertain, not only in the infestation rate or proportion of commodity units infested but more particularly in the pest load associated with an infestation. So, it is difficult to be certain about the proportion of a commodity infested, and even more uncertain how many units of a pest are present as potential propagules of new infestation. This must be regarded as one of the key limits of an absolute quantification of the pest load arriving in each Member State. However, knowledge of the relative pest load, based on trade volume, arriving in each Member State and region is valuable in helping to set priorities on management.

6.2. Level of detail in models

The general QPAFood models cover aggregate commodity movements on a monthly timescale from export sources at national level to destinations at EU NUTS2 level. All retail use is aggregated, but major processing use streams are segregated.

The consignment QPAFood models cover individual consignments through separate defined use streams on a daily timescale. The inputs within use streams are based on relatively generic information about the commodity, the pests and the process. However, very specific parameter values could be available for particular consignments if there is historical data on a particular pathway.

6.2.1. Problems in high detail

More detailed models require greater parameterisation effort, but if the estimates are highly variable the added effort of detailed parameterisation may not yield a result that is immediately useful. Sensitivity analysis can indicate which parameters are of highest importance. However, it can never be possible to address pest risks across a large area and time period in a way that includes local or short-term incidents of risk-causing behaviour or conditions.

A high level of detail necessarily implies a very large numbers of parameters. This can lead to practical difficulties of estimating all the parameters in order to apply the models to a given case. A high level of detail can also lead to wasted effort as there is a tendency to include precision where it is available but use general estimates where it is not. This leads to unbalanced models with very accurate information in some parts and very weak information in others. The inclusion of uncertainty values at least helps to indicate where such imbalances occur.

6.2.2. Benefits in high detail

Analysis indicates that risks based on data aggregated in space and time differ considerably from more specific cases, and outputs are more uncertain in aggregation.

The QPAFood models can provide much disaggregated temporal and geographical information about the nature and pattern of the pest risk. The models can also use detailed Eurostat data to maximum effect.

6.2.3. Approach to parameterisation which allows variable detail

Considerable effort has been made in the QPAFood project to reach a level of detail that is practically and generally available for the parameters in the models, and to demonstrate outputs of the models based on such data. The models are intended to be general models and so they have been designed with data limitations in mind. Distributions, with more or less uncertainty, are used throughout in the expectation that at least ranges and likely values can be estimated, so the models can operate with limited data in parts, but at the cost of greater uncertainty in output values.

The model parameter entry tables are provided in such a way that maximum detail can be included if available, for example the proportions of fruit being used for processing by individual Member States. If, however an indicative proportion is used for the EU as a whole, this value is simply copied across the range of input cells.

6.3. Generality in the models

6.3.1. A general fruit model and a general grain model

The three fruit models share a common structure and the experience with the model indicates that this is suitably generic for fresh fruits. The grain model is also intended to be general and includes livestock feed and milling uses that would be common to many grains other than wheat.

The fruit pathways had sufficient similarity that a single general fruit model could be developed. This has the advantage that the models can be applied to other fruit pest cases. There are differences, for example where the peel forms a separate waste stream. These differences are accommodated by parameterisation, so for example plum has no separate waste stream of peel whereas orange does. Only one grain-related model was developed, for wheat, but the model was built with flexibility of application in mind and the objective is that the wheat model could be applied to other grains by appropriate parameterisation. Wheat use is diverse and complicated and for some other grains, this will be less so. Particular pathways that are not relevant in other grains can be given 0% for that use type, which effectively switches off unused branches of the pathway.

6.3.2. Provision of a tool for other pests and commodities

The QPAFood models can be parameterised for a wide range of pest organisms. However, they have not been designed with anticipation of long lag times for pest activity, so this could require adaptation if that is a factor for specific pests. Risk assessments will be more certain for pests with narrow, commercial crop host ranges than for generalist pests, because the structure only allows a single or aggregated host area and phenology in each case.

The models use both data tables and parameters which are specific to the pest and commodity concerned. The data tables for trade and production are specific to the commodity. The data tables for human population (determining retail distribution), livestock distribution (determining feed distribution) and, processing enterprise distribution are expected to be common to different commodities. The models are provided with a consistent clear approach to parameterisation so despite the potentially large number of parameters, parameter entry requirements are restricted to certain clearly labelled sheets and within those sheets in clearly labelled cells. The application of the models to other commodities and pests requires some work to assemble parameter estimates but is intended to be achievable by the general user who has an understanding of pest risk analysis.

6.4. Features of the tools provided

Models of pathway entry can be very complex and QPAFood illustrates this complexity. An important feature of the QPAFood approach has been modularity and an interface that allows users to focus on each parameter or step in the pathway, while still seeing the wider context. It is expected that the models would be used in assessing risk scenarios, as well as making assessments on available data. The models are versatile in this respect, so that user inputs can be adapted for many different scenarios. The model structure is also intended to facilitate the creation of scenarios because the step by step approach provides a scenario outline.

The modelling tools are provided as systematically constructed spreadsheets which are clearly labelled and documented. The general model, which is more complicated, is provided with an interactive main page which allows navigation to all part of the models by the use of macro-buttons on the screens. The model calculations are available to view at all stages and the key results are also conveyed using graphical tools. The general model is provided in two modules which can be configured independently, so for example a series of trade or pest infestation scenarios represented in different realisations of Module 1 can easily be linked to the same distribution, use and host contact model in Module 2.

6.4.1. Insights from the case studies

Well-established trade in major commodities are relatively easy to assess with the QPAFood models. New trade requires assessment based on trade scenarios. Well-studied pests with narrow host ranges are more straightforward to assess within the models.

High volume trade to regions where consumption occurs in close proximity to host crops at susceptible stages poses the greatest pest risk, in principle. Spatial and temporal management of distribution chains could greatly reduce risks without additional direct treatment of commodities. The evidence of pest risk used as a basis for proposing any controls on trade chains needs to be considered at appropriate scales that reflect the scale of potential management units in the trade chains. While the QPAFood models have been built to NUTS2 regional and monthly scales these may not reflect the organisation and adaptability of food supply chains, which may be organised on larger spatial scales and very variable temporal scales.

The patterns of risk associated with the four case study pests and their commodity hosts yielded some interesting and potentially useful results for the understanding and management of the risk posed by alien species carried by fresh food trade. Two of the fruit case studies, apple and plum, showed a risk pattern in which risk was very concentrated on a specific Member State. For the orange and wheat case studies the risk was spread more widely over Member States. Within Member States the risk was very concentrated in certain NUTS2 regions but for the apple case study the risk was more widely spread within the high risk country. It was very clear that the patterns of risk between and within Member States was very different primarily due to trade pattern, host distribution and commodity distribution influenced by use.

A particular issue which came to light was the effect of geographical scale on risk perception. Those countries which had overall the highest risk, did not necessarily contain the NUTS2 regions which individually suffered the highest risk. This was in part due to the number of NUTS2 regions within a country, so that for example in Germany, which has 38 NUTS2 regions, the commodity arriving in the country has the potential to be divided over many sub-regions. In contrast Lithuania has only one NUTS2 region, so all the commodity arriving in Lithuania goes to that one NUTS2 region. Additionally, for a given area of host crop, large countries on average have proportionately less host crop in each NUTS2 region.

6.4.2. Insights of wider importance

The QPAFood models reinforce the importance of trade volume as a primary driver of pest risk. However, they demonstrate that specific use-streams and details of immediate dispersal of pest organisms are critical to the risk in particular regions and months. The spatial and temporal scale of the assessment is important in the interpretation of risk outputs.

Some but not all the results obtained for the case studies were as might have been expected, for example a high risk associated with the orange pest case study in high production areas like Andalucía and Murcia, but some were more of a surprise. The models are new in providing a very detailed description of the pattern of risk across and within EU Member States and regions. Some of the locations revealed as high risk could not have otherwise been predicted, for instance apples in East Anglia. Also the ranking of risk and the degree of equivalence in risk between particular sub-regions could not have been predicted without such an analysis. It is expected that corresponding insights would be provided in the use of the models for other commodities and pests.

6.4.3. Potential contribution to risk management and plant health

The general QPAFood models give an indication of the distribution of risks from specific pests on a monthly basis across EU NUTS2 regions. This allows priority setting for inspection, surveillance and other management for specific pathways. The model also allows comparison of risks from different source countries and months for specific pest-commodity sets.

Management practices that affect values of parameters in the models can be tested to determine their relative impact on risk reduction, in time and space. Conversely, changes in practices that may increase risk can also be analysed through modelling scenario values. The modular structure of QPAFood is particularly well-suited to analysing specific scenario components. Because transhipments within the EU are a part of the model, QPAFood can also be used as a tool to predict trade-assisted spread of new pests within the EU territory.

The QPAFood models can also be used as part of forensic investigations to determine how outbreaks may have arisen. If for example, an outbreak is suspected of originating in a particular country outside the EU or in a particular Member State, scenarios can be simulated to compare the expected risk distribution with the known occurrence of secondary outbreaks, or with trade patterns at the time of the likely introduction.

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Glossary and Abbreviations

CABI:	Centre for Agriculture and Biosciences International
CN code:	Combined Nomenclature Code for commodities; CN codes are used in Eurostat and elsewhere to identify commodity groupings
Commodity:	A type of plant, plant product, or other article being moved for trade or other purpose (FAO, 2016); the product traded, about which trade statistics are provided by EUROSTAT
Consignment:	A quantity of plants, plant products or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots) (FAO, 2016)
Consignment model:	Pathway model of the movement and distribution of individual consignments from source countries to destinations in the EU
EC:	European Commission
EFSA:	European Food Safety Authority
Entry of a consignment:	Movement through a point of entry into an area (FAO, 2016)
Entry of a pest:	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 1996)
EPPO:	The European and Mediterranean Plant Protection Organisation
EU:	European Union
EU28:	The 28 member states of the European Union
EUROSTAT database:	Database provided by EUROSTAT (a Directorate-General of the EC) with the aim to provide statistical information of its member states
FAO:	Food and Agricultural Organisation of the United Nations
FAOSTAT database:	Database provided by FAO
Generic model:	A model within the QPAFood project for one of the four product groups which can be appropriately parameterised to make it pest and commodity-specific
General commodity model:	A pathway model, within the QPAFood project, of an imported infested/infected commodity to and within the EU from source countries by month
Infested/infected commodity:	The trade commodity harbouring the pest of concern
IPPC:	International Plant Protection Convention
ISPM:	International standards for phytosanitary measures
Introduction:	Entry of a pest resulting in its establishment (FAO, 2016)
Module 1:	The first of two modules of the General commodity model; it concerns trade pathways based on the Eurostat data of five years of monthly trade volumes for each specific commodity into the EU28 from all source countries and territories

Module 2:	The second of two modules of the General commodity model; it concerns the allocation of commodity volumes to processing, retail use and waste streams and the potential for pest transfer to a suitable host
NACE:	The Statistical Classification of Economic Activities in the European Community; NACE codes are used in Eurostat and elsewhere to identify commodity groupings
NPPO:	National Plant Protection Organisation
NUTS2:	Nomenclature of Units for Territorial Statistics; for each EU member country, a hierarchy of three NUTS levels is established by Eurostat; NUTS2 is the intermediate level of spatial resolution and 270 sub-regions of the EU are identified at NUTS2 resolution
PRA:	Pest risk assessment (FAO, 2016)
QPAFood:	The name given to the suite of models comprising the generic General commodity model and the generic Consignment model commissioned by EFSA for quantitative pathway analysis of food commodities
Risk (in QPAFood pathway models):	The potential volume of infested commodity in potential contact with an area of susceptible domestic host crop
Sensitivity:	The change in model results associated with changes in the values of specific model parameters
Transhipment:	The movement of consignments of the commodity of concern which pass through an EU country en route to another EU country or a non-EU country
Transfer to suitable host:	The process in which a pest leaves the products in a consignment and comes into contact with a new host
Vulnerability:	The potential for pest transfer in a region if the pest is released from an imported commodity in that region

Appendix A – Case study: Sweet orange from all countries with potential infestation by *Xanthomonas citri* pv. Citri

A.1 Introduction

The project had already selected the case study commodities and pests as shown in Table A.1.01.

Table A.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities and pests

Commodity	Pest	Common name	Case study countries
Pome fruit: Fresh apples	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit: Fresh plums	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus: Sweet oranges	*Xanthomonas citri citri*	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries).
Cereals: Wheat	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

To inform parameterization of the pathway models for each commodity, this report collects information on:

- the distribution of pests at pathway origin,
- exports and pathway regulations and pest survival,
- trans-shipments,
- commodity uses,
- commodity processing and waste management, and
- location of processors.

The information is used to provide the rationale for selecting the estimated values for several of the quantitative inputs required in the quantitative models describing the likelihood of pest entry via selected case study pathways on one of four commodity types (Table A.1.01).

A.2 Seasonal orange imports by the EU

The EU is the largest importer of sweet oranges in the world. Between 2008 and 2011, an average of around 931 thousand tonnes of oranges was imported into the EU (EU 27) representing around 22% of the world's output. In addition, intra-EU trade of oranges originating in the southern EU Member States, Spain, Italy, Greece and Portugal over the same period amounted to around an average of 1,747 thousand tonnes per annum of which around 75% originated in Spain.

Third Countries exporting oranges to the EU can be divided into northern and southern hemisphere suppliers characterised by distinct orange export seasons which largely supply oranges to EU MS outside the main European harvest season (early November- end of May). Major northern hemisphere suppliers include the Mediterranean countries, USA and Cuba which historically have accounted for more than 80% of imports to

EU MS between January and June. Among the most important of the Mediterranean exporters in recent years have been Israel and Morocco followed by Egypt, Turkey and Tunisa. In contrast the orange export season of the major southern hemisphere producers -South Africa, Brazil, Argentina, Uruguay, Australia, Zimbabwe and Swaziland, lasts from June to November,

A.3 Occurrence of case study pest at origin

This case study is restricted to the risk of introduction of the causal agent of citrus canker, *Xanthomonas citri* pv. *citri* (*ex* Hasse 1915) Gabriel et al., into EU Member States. This and the closely related *X. citri* pv. a*urantifolii* are the only pathotypes causing significant damage to the citrus industry (Jetter et al., 2000; Spreen et al., 2003). Much of the information on the biology and distribution of the bacterium is derived from an earlier report on citrus canker eradication by the University of Florida, US (Schubert et al. 2001) and a more recent EFSA review of the pathogen (EFSA 2014).

Citrus canker, caused by *Xanthomonas citri* pv. *citri* (*X. citri* subsp. *citri*, *X. axonopodis* pv. *citri*) also known commonly as Asian citrus canker, is an EU quarantine disease of *Citrus* spp. characterized by corky lesions on leaves, fruits and twigs. The disease was first described by Stevens in 1915 and the causal bacterium, by Hasse in 1915 in the USA although the pathogen is thought to originate in Asia. Symptom development and spread of the bacterium are enhanced by the activity of the citrus leaf miner, *Phyllocnistis citrella*, which occurs in nearly all citrus growing areas of the world. In Europe is is established in the Iberian peninsula, Corsica, Italy, Greece and Montenegro (see Janse, 2012) and its effect in increasing the severity of the disease is caused by the damage caused by larvae mining under the surface of the leaves. Whilst this insect is not a true vector, bacteria present incidentally on the surface of larvae, can be carried into the leaves through the galleries produced by its mining activity.

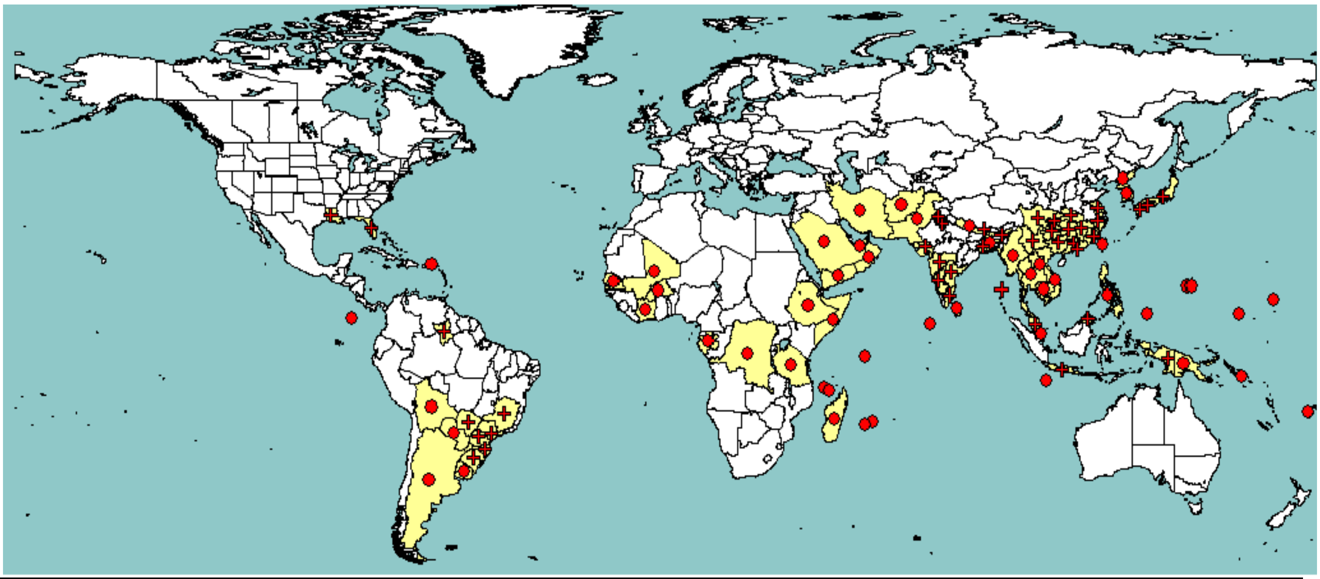
X. citri pv*. citri* is the most widespread and aggressive of a number of related strains or pathovars causing citrus canker. Grapefruit (*C. paradisi*), Mexican/Key lime (*C. aurantiifolia*) Palestine sweet lime (*C. limmetioides*), trifoliate citrus (*Poncirus trifoliate*), *C. hystrix* and sweet orange (*C. sinensis*) cultivars Hamlin, Navel and Pineapple are the most susceptible species affected by *X. citri* pv. *citri* strain A (Asiatic canker, Oriental canker or canker ‘A) Other varieties of sweet orange, along with lemon (*C. limon*), sour orange (*C. aurantium*), tangelo and pummelo (*C. maxima*) are generally considered to be moderately susceptible. A second group of strains designated A* reported from Cambodia, Oman, India, Iran and Saudi Arabia, considered to be distinct from other A strains of the pathogen (Whiteside, 1985), is restricted to Mexican lime, and Tahiti lime (*C. latifolia*) but not grapefruit whilst a third group of strains designated Aw infect Mexican lime and alemow (*C. macrophylla*) in Florida, USA (Sun et al., 2004).

South American canker (cancrosis B) caused by *X. citri* pv. *aurantifolii*, is presently confined to South America and Mexico on lemons, Mexican lime, sour orange and pummelo, whilst strains within *X. citri* pv. *aurantifolii,* cancrosis C, presently confined to Sao Paulo, Brazil, infects only Mexican lime and sour orange whilst cancrosis D is restricted to Mexican lime in Mexico (Janse, 2012).

A.4 Current distribution

The global official distribution of *X. citri* pv. *citri* and *X. citri* pv. *aurantifolii* from the EPPO-PQR database (EPPO 2014) is shown in Figure A.4.01 and Annex B. In addition, *X. citri* pv. *citri* was reported recently from Louisiana (NAPPO, 2013). The geographical distribution of *X. citri* pv. *aurantifolli* is restricted to Argentina, Brazil, Paraguay and Uruguay (Rossetti, 1977).

Figure A.4.01: World distribution of *X. citri* pv *citri*



X. citri pv. *citri* originates from and is widespread in Asia, including Georgia, Iran, Iraq, Oman, Saudi Arabia, UAE and Yemen. Australia (eradicated), Argentina, Belau, Brazil, Caroline Islands, Cocos Islands, Comoros, Congo Democratic Republic, Ivory Coast, Fiji, Gabon, Madagascar, Mauritius, Mozambique (eradicated), Netherlands Antilles, New Zealand (eradicated), Micronesia, Palau, Papua New Guinea, Paraguay, Reunion, Seychelles, South Africa (eradicated), Uruguay, USA (CABI/EPPO, 2006). There are recent reports from Somalia (Balestra *et al.*, 2008) Mali (Traoré *et al.*, 2009) and Ethiopia (A* strains, Derso *et al.*, 2009). A full list of countries where *X.citri* pv. *citri* is known to be present is documented later in this Appendix.

The pathogen is present in or has occurred and been eradicated from a number of major exporters of sweet orange to the EU. These include Argentina, Australia, Brazil, USA and Uruguay. The European Commission recognises certain countries as being free from *X.citri* pv. *citri* (Anon 2006; 2013). A summary of these countries is given below (Table A.4.01).

Table A.4.01: Countries accepted as being free from *X. citri* pv. *citri* (EC Decision 2006/473)

Continent	Countries free from *X. citri* pv *citri*	Countries with limited distribution of *X. citri* pv *citri*	Regions where *X. citri* pv *citri* is known to be absent	Regions where *X. citri* pv *citri* is known to be present
	all citrus-growing third countries in Europe, Algeria, Egypt, Israel, Libya, Morocco, Tunisia and Turkey			
Africa	South Africa, Gambia, Ghana, Guinea, Kenya, Sudan, South Sudan*,Swaziland and Zimbabwe			
Central and South America and the Caribbean	the Bahamas, Belize, Chile, Colombia, Costa Rica, Cuba, Ecuador, Honduras, Jamaica, Mexico, Nicaragua, Peru, the Dominican Republic, Saint Lucia, El Salvador, Surinam and Venezuela	Brazil		States of Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Minas Gerais, Maranhão*, Mato Grosso*, Mato Grosso do Sul and Roraima*
Central and South America and the Caribbean		Uruguay		Departments of Salto, Rivera and Paysandu — north of River Chapicuy
Oceania	New Zealand			
Oceania		Australia	New South Wales, South Australia and Victoria	
		US	Arizona, California, Guam, Hawaii, Louisiana, Northern Mariana Islands, Puerto Rico, American Samoa, Texas and the United States Virgin Islands	

A.5 Pathogen life cycle: *X. citri* pv. *citri*

X. citri pv. *citri* enters the plant tissue primarily through stomata and wounds caused by insects, wind-driven rain and orchard management operations. Minimum and maximum temperatures for multiplication in plant tissue are 12 and 40 °C, respectively, with the most favourable temperature range being 25-35 °C (Dalla Pria et al., 2006). Latent infections may occur below the minimum temperature, but above 5°C, for multiplication. These may become active when both the temperature and growth stage of the plant are favourable for disease development (Peltier, 1920). At temperatures favourable for disease development (25-35°C), the length of the latent period ranges from a few days to a week (depending on host, wound availability and inoculum pressure), while it increases at lower temperatures. There are no data on the latent period length on fruit, although, again, it is dependent on temperature and is likely to be in a similar range to that on leaves.

Disease severity increases with the duration of leaf wetness and the presence of wounds. Mining by larvae of the Asian leaf miner causes extensive leaf damage which allows ready acess by the pathogen and is, therefore, highly conducive to disease development. Providing the temperature is in the optimum range *X. citri* pv. *citri* will readily exude from canker lesions during wet periods, providing inoculum for further infection (Timmer *et al*., 1991; Pruvost *et al*., 2002), the severity of which increases with increasing duration of leaf wetness (Dalla Pria *et al*., 2006).

In orchards, infections occur and spread rapidly at warm temperatures, with prolonged rain or overhead irrigation, when trees are in a susceptible stage of development for infection to occur. This is normally during the periodic growth flushes and when fruit is in early active development. Storms severe enough to cause damage to leaves and fruit facilitate spread of infection as does wounding by insects In particular sub-epidermal galleries created by the Asian citrus leafminer, enhance infection (Gottwald *et al*., 1997; Christiano *et al*., 2007; Gottwald *et al*., 2007). Resistance of leaves, stems and fruit increases with tissue age (Stall *et al*., 1982; Vernière *et al*., 2003). Leaves are most susceptible to stomatal infections when half to two-thirds expanded (Graham *et al*., 2004) but can be infected at all stages of development when the leaf tissue is damaged. Fruit also is not susceptible to infection in the absence of wounds when fully mature.

Bacterial multiplication and spread is also determined by plant resistance. Spread in grapefruit orchards is rapid under conducive environmental condition because grapefruit is highly susceptible to *X. citri* pv. *citri*. Spread is also rapid in the susceptible sweet orange cultivars Hamlin, Navel and Pineapple which are the most susceptible sweet orange varieties. Infection and spread among other less susceptible sweet orange varieties is lower when plants are uninjured. Following pressurised spray inoculation, undamaged fruit is susceptible to infection 60-90 days after fruit set when fruit size is in the range of 20-40mm diameter. However, wound inoculation of sweet orange cv. Pineapple fruit has been shown to be successful over a period of 120-150 days (Graham *et al*., 1992; Vernière et al., 2003). Both older fruit (>60mm diameter) and very young fruit (<20mm in diameter) also showed reduced susceptibility to infection.

A.6 Survival in host tissue

X. citri pv. *citri* can survive for extended periods in cankers on diseased leaves, fruits and twigs. (Gottwald *et al*., 2002a; Graham *et al*., 2004). Pruvost *et al*., (2002) estimated population levels of 10^5 cfu/ml of cells of *X. citri* pv. *citri* recovered from 18 month old leaf lesions and Das (2003) demonstrated survival in dry, infected tissues free from soil for up to several years, illustrating that the pathogen can readily survive from season to season in cankers on infected branches (Gottwald et al., 2002a; Graham et al., 2004). Survival is lower where a marked winter season occurs. (Stall *et al*., 1980) and the pathogen dies out within a few months when infected leaves are incorporated into soil (Gottwald et al., 2002a). Saprophytic survival of the pathogen in soil free from plant debris has not been demonstrated conclusively (Goto, 1970; Goto et al., 1975 a, b; Graham et al., 1987; Graham and Gottwald, 1989).

A.7 Survival outside host tissue

The ability of *X. citri* pv. *citri* to survive outside of citrus tissues is low. The pathogen was reported to survive asymptomatically at low population levels on citrus host surfaces or in association with non-citrus weed and grass plants (Goto, 1970, 1972; Goto et al., 1975, 1978; Leite and Mohan, 1987). The pathogen can survive for between 24 and 72 hours on inert surfaces depending on the environmental conditions but dies out more rapidly when the surface is dry (Graham et al., 2000). This demonstrates a potential risk of spread of infection during husbandry operations in the orchard. Theife-cycle of Xanthomonas citri pv. citri, the pathogen causing citrus canker disease, is illustrated by USDA (2007).

A.8 Disease management on farm

EU legislation requires that citrus for the EU market should be produced in orchards free from *X. citri* pv*. citri.* However, management practices will vary between citrus growers within an exporting country as well as between countries. The US and South American producers generally grow citrus on larger well managed orchards in which citrus canker can be managed by good hygiene and regular spraying with copper-based chemicals. In some other countries, citrus is grown on a smaller scale where produce of a number of farmers is aggregated before or at the packing station.

Prophylactic sprays of copper-containing compounds are used to protect disease-free places of production from contamination from adjacent orchards which may have diseased plants. Spraying is normally carried out during growth flushes and at early stages of fruit development when trees are most susceptible to infection (Stall *et al*., 1980; Leite and Mohan, 1990; Graham and Leite,; Das, 2003; Kuhara, 1978; Koizumi, 1977; Timmer, 1988). During rainy periods the copper compounds are progressively washed off the plants, necessitating additional spray applications. The number of sprays required is also dependent to some extent on the susceptibility of the citrus host being cultivated. In Japan, susceptible hosts are often sprayed 5 to 7 times, while moderately susceptible cultivars are only sprayed 4 times throughout the growing season. Use of copper-based sprays can be highly effective in reducing disease incidence. Leite et al (1987) demonstrated a reduction of 90% disease in moderately susceptible citrus cultivars on orchards receiving five to six copper sprays during the highly susceptible rainy season in Brazil.

Citrus orchards located in areas where citrus canker is endemic are at risk of infestation by *X. citri* pv. *citri* in surrounding orchards. In Florida, US, a number of researchers (Gottwald, 2002a; Gottwald *et al*., 2001; Compton and Fagan, 2000; McElroy, 2000).demonstrated that the pathogen is capable of spreading 1900 ft from the source, 95% of the time. Other researchers have shown the pathogen to be capable of spreading from from 32 meters to several miles (Stall *et al*., 1980; Gottwald *et al*., 1988, 1992, 2002b; Timmer et al., 2000) under favourable conditions (wind-driven rain). Bacteria can infect uninjured leaves through stomata when wind speeds are above 8 m/sec Timmer *et al*., 2000) and thereafter, bacteria are dispersed within trees, and from tree to tree through wind-driven rain.

A.9 Likelihood of infestation at harvest

Most orange fruit are still harvested by hand, especially for the fresh fruit market, using trained pickers, who can recognise and pick only marketable fruit and avoid diseased or otherwise inferior fruit. The skill of the pickers in recognising and discarding diseased and blemished fruit may vary between citrus growers in different citrus growing areas. Harvested fruit is put in a collecting bag or basket to minimise damage and transferred to larger wooden or plastic collecting bins when full. When these are full, they are transported by truck or tractor to the packing house for sorting, storage, packing and/or marketing. In small operations packed fruit may be sold directly on local markets whilst in bigger operations fruit may be stored in cold storage at 4-15°C and 90-95% RH (Ohioline, 2003) or controlled atmosphere storage room. Based on market demand fruit is released from storage for processing and packing (Tao, 2003).

In commercial operations, most of the diseased, damaged, disfigured, and blemished fruits are culled in the field. Visual and/or automatic inspection at the packing house further reduces the possibility of diseased, damaged or blemished fruit being packed. This can be highly effective. Ploper et al (2004) reported that for citrus fruit grown for the EU market, harvested in Argentina, had < 1% symptomatic fruit after culling in the field, demonstrating the high level of effectiveness in removing such fruit. This resulted in almost zero symptomatic fruit reaching the packing bench and zero symptomatic fruit being packed. Occasional interceptions of *X. citri* pv. *citri* in citrus fruit arriving in the EU suggests that there may be some variability between packing stations resulting in some symptomatic fruit escaping detection. In addition, control procedures are likely to be less efficient in some Less Developed Countries as demonstrated by the higher levels of interceptions on arrival in the EU (table 3).

Depending on disease pressure, orchard spray and husbandry regimes, epiphytic populations of *X. citri* pv. *citri* may occur on growing citrus plants without progressing to cause active infections. However, several studies have shown that when orange fruit becomes detached from the tree, population levels fall. For example, Shiotani et al. (2009) found that the pathogen could not be detected on artificially infested fruit after three days suspended in an orchard in mesh bags. This supports research carried out by Goto (1962, 1969) which demonstrated survival between 8 and 72 hours in shade and sun and by Belasque and Rodrigues-Neto (2000) which reported less than five days on artificially infested fruit under laboratory conditions. More recent work (Gottwald et al., 2009) reports a significant loss of viability of the pathogen after harvest with no viable bacteria recorded from lesions on harvested fruit after 22 days. Furthemore, they also reported that in all experimental conditions no harvested mature fruit ever developed new *X. citri* pv. *citri* lesions.

Contribution to model input parameters

Likelihood of infestation at harvest

Studies by Ploper et al (2004) demonstrated the number of diseased fruit surviving culling at harvest to be <1%. However, considerable variation is likely day to day on and between orchards and the efficiency is likely to be much lower in orchards in Less Developed Countries. As a result, a conservative range would be from a minimum of ~1% for the best managed orchards in countries such as the US, Japan and S. American countries, to a maximum of around 5% for some smallholder operations in Less Developed Countries.

Epiphytic populations of *X. citri* pv. *citri* are likely to be present on fruit at harvest. Survival times of between three (Shiotani et al.,2009) and five (Belasque and Rodrigues-Neto, 2000) days have been reported

A.10 Likelihood of infected or contaminated fruit escaping detection in the packing station

Fruit from the field or storage passes through a number of processes aimed at extending shelf life before it is packed and shipped to the consumer. These include cleaning, waxing, treating and sorting. Transfer from storage containers to the conveyer may be carried out by flotation or gradually tipping the oranges onto a slow moving conveyer adjusted to a rate which controls the volume of fruit fed to the packing line. Fruit is then prewashed using water, and often a detergent to remove dirt, spray residue and natural wax. In commercial packers involved in the export market this is followed by dipping in 200ppm chlorine and/or sodium orthophenylphenate (SOPP) for 2 minutes to kill surface bacteria, with rotating brushes often used to carry out the cleaning as well as to convey the fruit along the line. In some experiments using this procedure, *X. citri* pv. *citri* populations have been reduced to epidemiologically insignificant or undetectable levels (Brown and Shubert, 1987; Graham and Gottwald, 1991; Canteros 2004). Another study using 200ppm chlorine without a detergent reduced surface populations of bacteria by 77-99% (Stapleton, 1986). Fruit is often passed over drying and polishing brushes after cleaning. At this stage fruit may be sprayed with wax to improve appearance and shelf life followed by further drying at 58°C for 2.5 minutes (Schubert *et al*., 1999) to ensure stability of the wax coating on the fruit. This procedure might be expected to further deplete remaining *X. citri* pv. *citri* present after washing and chemical treatment.

Fruit is then conveyed, usually by a roller conveyer, to the inspection and sorting area where remaining defective fruit is removed and the remainder graded. In larger packing houses machine vision equipment may be used to sort fruit into different grades based on weight, dimensions, colour, shape, infection and defects. After grading, the fruit passes through a mechanical sorting machine which discharges fruit along its length according to grade. Fruit is then conveyed to its packing location, with measures incorporated to minimise damage. Fruit is then packed into containers, designed to avoid damage during transport. Packing is often carried out by hand and packed into cartons in such a way to avoid movement of fruit during transport, thereby reducing damage. (Tao, 2003)

The bulk of diseased, damaged and blemished fruit is removed before it arrives at the packing house. Some fruit showing symptoms may escape detection as well as symptomless fruit, and fruit which is contaminated with latent or epiphytic populations of *X. citri* pv. *citri* ,on the fruit surface. Research in Argentina has shown that culling of symptomatic citrus fruit is highly effective in packinghouse operations. In a study in which trays of fruit were deliberately mixed to give either 1% or 3% levels of infected fruit, followed by normal commercial-practice visual inspection at three stages of the packing process, extremely low (near zero) numbers of symptomatic, injured or blemished fruit reached the packing bench, with zero symptomatic fruit packed in boxes. It was concluded that infected fruit levels of upto 4% would be detected using normal commercial inspection procedures (Ploper *et al.*, 2004).

Further analysis concluded that the data of Ploper *et al.* (2004) could only confirm that the daily average of symptomatic citrus fruit rate passing the inspection line is below 0.0042%. The data show dependence between prevalence (between 0.2% and 4%) and the remaining symptomatic citrus fruit rate (upper confidence interval (CI) between 0.0008% and 0.0042%). But also for a given prevalence below 1% it can not be excluded that the remaining symptomatic citrus fruit rate is up to 0.002 %.(EFSA, 2011)

Contribution to model input parameters

Likelihood of infestation after packing station procedures

The EFSA(2011) interpretation of the observations of Ploper et al (2004) suggest that with an initial infestation level of 1 and 3%, respectively the daily average of symptomatic fruit passing the inspection line is 0.0042%. Remaining infection levels at initial prevalence of diseased fruit of between 0.2 and 4% is 0.008 and 0.0042% whilst with an initial prevalence of <1% thr remaing symptomatic fruit surving the packing procedure will be upto 0.002%. Epiphytic bacterial levels on fruit surface reduced by 77-100% (Stapleton, 1986; Graham and Gottwald, 1991; Canteros 2004).

Within EU phytosanitary legislation, citrus fruit from outside the EU are regulated articles subject to the EC Plant Health Directive (2000/29/EC, 8 May 2000). The EC Plant Health Directive uses the synonym *Xanthomonas campestris* (all strains pathogenic to *Citrus*), in Annex II Part A Section 1 for *Xanthomonas campestris* pv. *citri* and *X. citri* pv. *aurantifolii.* This means that the organism is regarded as a harmful organism whose introduction into, and spread within, all Member States shall be banned if present on plants of *Citrus, Fortunella, Poncirus* and their hybrids other than seeds. Annexes III; IV AI and VB of that Directive list requirements for the introduction into the EU of citrus plants, including fruits, which could be a pathway for the entry of this pathogen. In addition, temporary emergency measures are in place which impose additional requirements for the import of certain citrus fruits from Brazil in connection with *Xanthomonas campestris* (all strains pathogenic to Citrus) (Commission Decision 2004/416/EC; OJ L 151, 30.4.2004, p. 76).

Special requirements for the introduction and movement into and within MS of fruit of *Citrus, Fortunella, Poncirus* and their hybrids originating in third countries are detailed in Annex IV Part A, Section 1 (points 16.1 and 16.2) of the EC Plant Health Directive.

Before export, sweet orange fruit from third countries must be inspected and found free of quarantine pests. If consignments are free from quarantine pests, then a phytosanitary certificate can be issued for export to the EU.

ISPM No. 31 on sampling of consignments, provides guidance as to how many lots (e.g. boxes of fruit), are to be sampled within a consignment depending on the size of the consignment (i.e. how many lots), the degree of pest infestation (5%, 2%, 1%, 0.5% and 0.1%) and the level of confidence required (80%, 90%, 95% or 99%). Sampling size increases as the level of infestation lowers and the confidence required increases.

Imported (and home produced) fruit and vegetables are subject to EU Marketing Standards which align with United Nations Economic Commission for Europe (UNECE) standards. Specific European Union marketing standards exist for citrus. The standards may be found in EU Commission Regulation 543/2011, UNECE (2012) and FAO Codex standard CXS-245-2004 (Codex, 2004). Freshfell Europe (2011) provides a summary of EU marketing standards for citrus fruit (Appendix 2). In summary, fresh oranges are required to be checked for conformity with EU marketing standards for quality and labelling. Oranges must be "practically free from pests". "Practically free" is a recognised phytosanitary term used by IPPC and defined in ISPM No. 5 as …"*Of a consignment, field or place of production, without pests (or a specific pest) in numbers or quantities in excess of those that can be expected to result from, and be consistent with, good cultural and handling practices employed in the production and marketing of the commodity*". Such quality checks in an exporting country could lead to oranges being rejected for export to the EU as a conformity certificate is required for all fresh produce shipments destined for the fresh market.

A.11 Shipping oranges

- Shipping conditions required for oranges are outlined in the Association of the German insurance industry (TIS, 2015). To minimise losses during shipping a number of procedures are routinely carried out in the packing house. These include:
- Post-ripening of green or unsatisfactorily coloured fruit
- Removal of dirt, sooty mould, spraying residues and scale insects in washers.
- Finishing of oranges which do not develop the typical orange colour in a dye bath at temperatures of 45 - 50°C
- Coating with a layer of wax and treatment with preservatives to replace natural wax removed in washing and preserve the aroma. The wax layer only partially seals the pores on the fruit allowing respiration to occur
- Grading of the fruits by size (gauging), colour and other external features.
- Counting, weighing and packing. Marking each package with details of number of fruit, quality class, variety and origin.
- Storage in cold stores until shipment.

The maximum storage time during shipping is around 16 weeks at temperatures in the range 6-10°C, depending on the variety. Relative humidity is maintained in the range 85-90% to prevent fluid loss from the fruit. This is longer when controlled atmosphere transport (10% oxygen, 5% carbon dioxide) is used.

The required refrigeration temperature be maintained throughout the cargo handling and shipping operation to prevent deterioration of the fruit.Whilst most oranges can withstand a temperature of 5°C this depends on the variety and ripeness and more sensitive varieties are shipped at a temperature around 10°C. In damp weather (rain, snow), the cargo is protected from moisture, to reduce risk of premature spoilage.

During shipping, oranges are stowed under cool, dry conditions with adequate ventilation to prevent growth of moulds and in such a way to prevent abrasion and pressure damage which will lead to spoilage. To meet these requirements oranges are mainly transported in cartons, boxes, or fruit crates made of corrugated board or wood. The normal consignment size is 20 tonnes.

During loading and shipping, pulp temperature measurements are carried out regularly to ensure that they remain in the range of 4 to 25-30°C to maintain storage life and quality.

A proportion of bacteria surviving the post-harvest treatment are likely to survive shipping. Bacteria remaining on the fruit surface either epiphytically or in lesions are not known to multiply or cause disease development although a proportion in lesions remain viable as demonstrated by interceptions and laboratory testing of symptomatic material in the importing country.

Experiments carried out in Spain on citrus fruit imported from South American countries (Golmohammadi *et al*. 2007) used three PCR protocols and real-time PCR resulted in detection of *X. citri* pv. *citri* in eleven of fifteen symptomatic fruit and in 16 out of 130 lesions on the fruit using PCR. Viability was confirmed by pathogenicity tests on grapefruit. In further work using different conventional PCR protocols *X. citri* pv. *citri* was detected in 39-52 lesions whilst using real-time PCR, using SYBR green or a Taqman probe, *X. citri* pv. *citri* was detected in 58 and 80 lesions respectively.

Contribution to model input parameters

Likelihood of infestation after shipping

Golmohammadi *et al* (2007) in 73% of imported citrus fruit showing canker lesions and between 12 and 61% of lesions on the fruit.

No data are available for survival of epiphytic populations of *X. citri* pv. *citri* although packing station treatment reduce such populations by 77-100% and further loss of viability is likely during shipping. However, likely to be a lot of variation between packing stations within and between producer countries.

A.12 Transhipment of oranges

Most of the EU-28 import fresh citrus fruit. Some of these citrus fruit originate from countries where citrus canker is widespread: more than 280 kt from Argentina, 90 kt from Uruguay, 83 kt from Brazil and 47 kt from China in 2011 (EUROSTAT, online). Citrus-producing countries of the EU-28 import large amounts of fresh fruit mostly during spring and summer from countries where *X. citri* pv. *citri* is widely present. High quantities of fresh citrus fruit imported into the EU from third countries are re-distributed in the internal market by many Member States (i.e. Netherlands, Belgium, Germany, France, UK). In 2008, the Netherlands imported from third countries around 390 kt of sweet orange (one-sixth of which originated from countries where *X. citri* pv. *citri* has established) and distributed approximately 180 kt of sweet orange to other EU countries, including citrus-producing countries (EUROSTAT, online). A trade network for movement of sweet oranges in Europe is shown at the end of this Appendix.

A.13 Interceptions of X. citri pv. citri by EU Member States

A total of 314 interceptions of *X. citri* pv. *citri* have been made by EU Member States between 2003 and 2014 (Table A.13.01). A total of 267 of interceptions, representing 85% of the total was in citrus fruit imported from the minor exporting countries of the Indian sub-continent (Table A.13.01; Figure A.13.01). Consignments from Bangladesh had the greatest number of interceptions (161), representing 51% of the total, followed by Pakistan (77) with 24.5% and India (29) with 9.2% of the total. Outside the Indian sub-continent 4.8% of the interceptions were in citrus imported from Argentina with the remaining interceptions from Uruguay, Malaysia, Thailand, Mexico and Sri Lanka. Two EU Member States accounted for 97.1% of the interceptions, with the number of interceptions by the UK (282) representing 89% of the total, followed by Spain with (23) representing 7.3% of the total. No interceptions were made from Brazil or the USA over the period, suggesting that an effective management system is in place in these countries to exclude symptomatic fruit from the export trade.

Table A.13.01: *Xanthomonas citri* pv*. citri* interceptions reported in EUROPHYT on fruit consignments 2003 - 2014 (Source: EUROPHYT)

Origin	UK	Spain	Italy	France	Germany	Greece	Total
Bangladesh	161						161
Pakistan	76				1		77
India	28				1		29
Uruguay	3	10	2			2	17
Argentina	2	11	1	1			15
China	3			1			4
Malaysia	4						4

Thailand	4						4
Mexico (a)		2					2
Sri Lanka	1						1
Grand Total	282	23	3	2	2	2	314

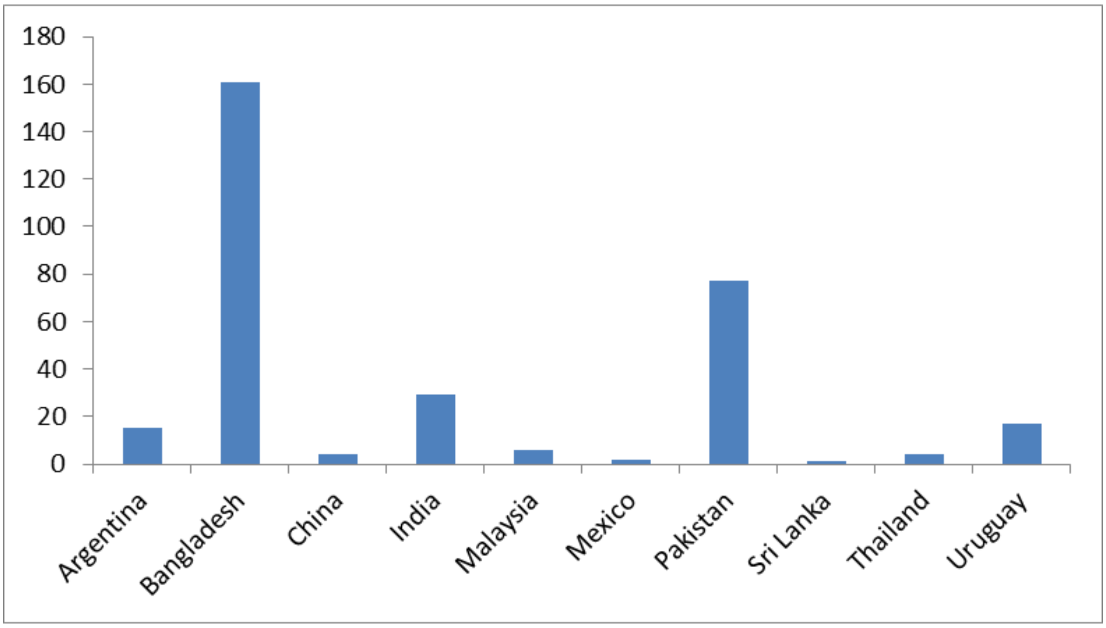


Figure A.13.01: *Xanthomonas citri* pv. *citri* interceptions reported in EUROPHYT 2003-2014

A.14 Oranges used in processing

The most important uses for sweet orange globally are consumption of fresh fruit or production of juices. It is likely that most oranges imported from third countries are used for domestic consumption although in years of reduced harvest in the main European citrus producing countries, a greater proportion may be processed to produce fresh and concentrated juices. Information from importers suggests that under normal circumstances around 10% of oranges from third countries are processed.

Approximately half of orange production either goes to waste in the form of peelings, representing a significant environmental liability in terms of disposal, or is used in other industrial processes. The two main options for disposal of peelings from domestic consumers are incineration and landfilling, but these contribute directly to greenhouse gas emissions. The larger industrial juice producers may pelletise the waste and sell it as cattle feed, although this process involves additional expenses and increased energy use because of the requirement to reduce the water content of the peel from around 80% to around 10% by weight before it can be pelleted and sold. In addition, because waste peel comprises only 6-8% protein and 40% fibre (See Pfaltzgraff, 2014) it is not particularly nutritious when used alone.

Other components of orange peel include soluble sugars, cellulose and hemicellulose, pectin, D-limonene and other minor constituents or derivatives which can be extracted or produced (Table A.14.01).

Table A.14.01: Some products produced from waste orange peel

Bio-ethanol	Produced by fermentation of citrus molasses and used as a fuel
Cattle feed	Dried (10-12% moisture) pulp is either sold loose or as pellets and the liquor is heated to produce a concentrate with around 72% sugars (citrus molasses) which is either returned to the dried pulp process or used as a feedstock for ethanol production.
Cellulose	Used as a thickening agent or raw material for production of a solid biofuel
Compost	Used in horticulture (Bernal-Vicente *et al.*, 2008).
D- Limonene (~3.8% dry wt.)	Fragrant oil used as a component of household cleaners, adhesives, degreasers, flavours, diluents for other flavours and as a solvent it has the potential to replace petroleum-derived products.
Flavonoids	The principal flavonoid is hesperidin, an antioxidant used in the food and pharmaceutical industries.
Marmalade	Foodstuff
Methane	Used as a fuel
Pectin	Used as a gelling agent and thickener in cosmetics, pharmaceuticals and in the production of jellies
Pectin enzymes	Used in processes involving the degradation of plant materials, such as speeding up the extraction of fruit juice from fruit, as well as in wine production
Single cell protein	Used as a substitute for protein-rich foods, in human and animal feeds.
Succinic acid	Used as a precursor in production of some specialized polyesters as an acid regulator, additive and dietary supplement in the food and beverage industry

By far the greatest proportion of oranges used for domestic consumption and processing comes from the domestic production and internal trade from the main European citrus producers Spain, Italy, Greece, Portugal and, to a lesser extent, France. Oranges imported into the EU to fill shortfalls in domestic production represent, on average, only between 13 -14% of local production. In recent years import of oranges from third countries where X. *citri* pv. *citri* is endemic, account for only 1-2% of local production and 12-13% of total sweet orange imports. Around 79% of the total supply is used for domestic consumption, with 17% used in the processing industry with the remainder being exported (Table A.14.02).

Table A.14.02: EU28 supply and usage for marketing years (October-September) 2011/12 to 2014/15. (Source: Valverde, 2013; Bettini,2014)(1,000 MT)

Market year begins November	**2011/2012**	**2012/2013**	**2013/2014**	**2014/2015**	**Mean 2011/2015**
Supply					
Production	6,023	5,890	6,712	6,207	6,208
Imports	848	888	821	826	852
Total Supply	6,871	6,778	7,533	7,033	7,061
Total imports from countries with Xcc*	125	126	98		116
Uses					
Fresh domestic consumption	5,536	5,387	5,757	5,386	5,560
For Processing	1,056	1,069	1,483	1,314	1,203
Exports	279	322	346	333	316
Total Distribution	6,871	6,778	7,533	7,033	7,061

*Argentina, Australia, Brazil, US, Uruguay: Xcc: *Xanthomonas citri* pv. *citri*

A.15 Process steps in the production of orange juice

Production of not for concentrate orange juice involves a series of process steps:

- Inspection and removal of debris
- Grading and sizing
- Washing
- Crushing of fruit to extract juice
- Straining, Filtration and clarification
- Removal of pulp and oil (finishing)
- Blending Pasteurisation.
- Filling, Sealing and sterilization
- Cooling, Labelling and Packing

Vaccuum evaporation is used to produce concentrated juice which in which water is drawn out of the fruit until the original volume is reduced by around 80%. Concentrated juice is produced for the export trade to reduce transport costs. It is reconstituted by adding an appropriate amount of water before sale.

During the processing of oranges to produce juice by-products such as limonene and molasses may also be produced. Waste peel may also be dried comminuted and pelleted for use as cattle feed although this is only economic if more than 50,000 tonnes of fruit is processed per year (Pfaltzgraff, 2014). Figure A.15.01 illustrates the steps in the production of juice and by-products.

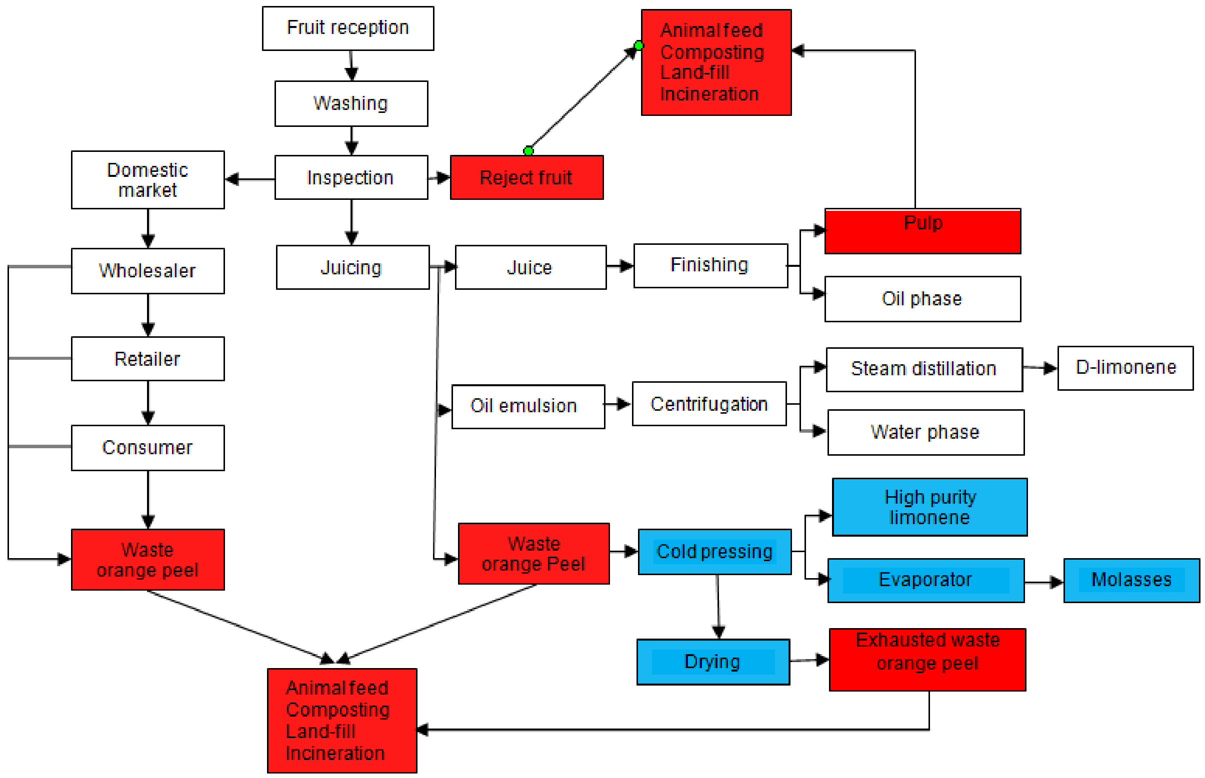


Figure A.15.01: Retail pathway for fresh oranges and juice extraction process for production of orange juice and by-products (Source: Adapted from: Pfaltzgraff, 2014 and other sources)

In Figure A.15.01, waste streams are shown in red and the steps in the production of molasses and high purity limonene in blue as the latter process is not universally included in the juicing process. Limonene is recovered by either cold pressing or steam distillation of peel after extraction of the juice and molasses, and/or waste peel, may be used as a feedstock for production of bioethanol (Zhou et al., 2007). The solid post-fermentation waste from this procedure may also be dried and pelleted for use as cattle feed. Dedicated processing plants are occasionally developed for the commercial extraction of limonene from waste orange peel.

Citrus peel is a principal feedstock in the production of some 35,000 tonnes of pectin per annum for use in the production of gelling agent in jam and bakery products as well as a stabiliser in dairy drinks (Pfaltzgraff, 2014). It is not a by-product routinely produced during juice extraction but is extracted separately from waste peel after pasteurisation and rapid drying to avoid destruction of the pectin by pectolytic enzymes present in the peel. Pectin is produced commercially by a process of acid hydrolysis which results in the production of large amounts of acidic waste-water which is expensive and difficult to neutralise. Up to 170 kg of water is required for the production of each kilogram of pectin.

After washing and drying the waste peel used as feedstock, pectin is extracted by acid hydrolysis using hydrochloric or nitric acid, followed by filtration, ion exchange and concentration. It is then precipitated using propanol and de-esterification using alkali or acid and alcohol. The resulting product is washed, dried, milled and blended to produce commercial pectin (Pfaltzgraff, 2014).

Waste orange peel is also used as a feedstock for the commercial extraction of upto 0.45% of the flavonoid hesperidin (Pfaltzgraff, 2014) along with a number of other flavonoids with lower commercial value.

Washed peel is treated by grinding, addition of lime, alkali extraction at pH 11, followed by pressing, crystallisation,filtration and drying to produce around 4kg/tonne of hesperidin used as an anti-oxidant in the food and pharmaceutical industries.

A common procedure in all the above commercial operations is the washing of whole oranges before processing and washing the waste peel before use as a feedstock in the production of animal feed, alcohol, limolene and hesperidin. Waste water from this procedure presents the greatest risk of being contaminated with live bacteria.

A.16 Location of fruit processors

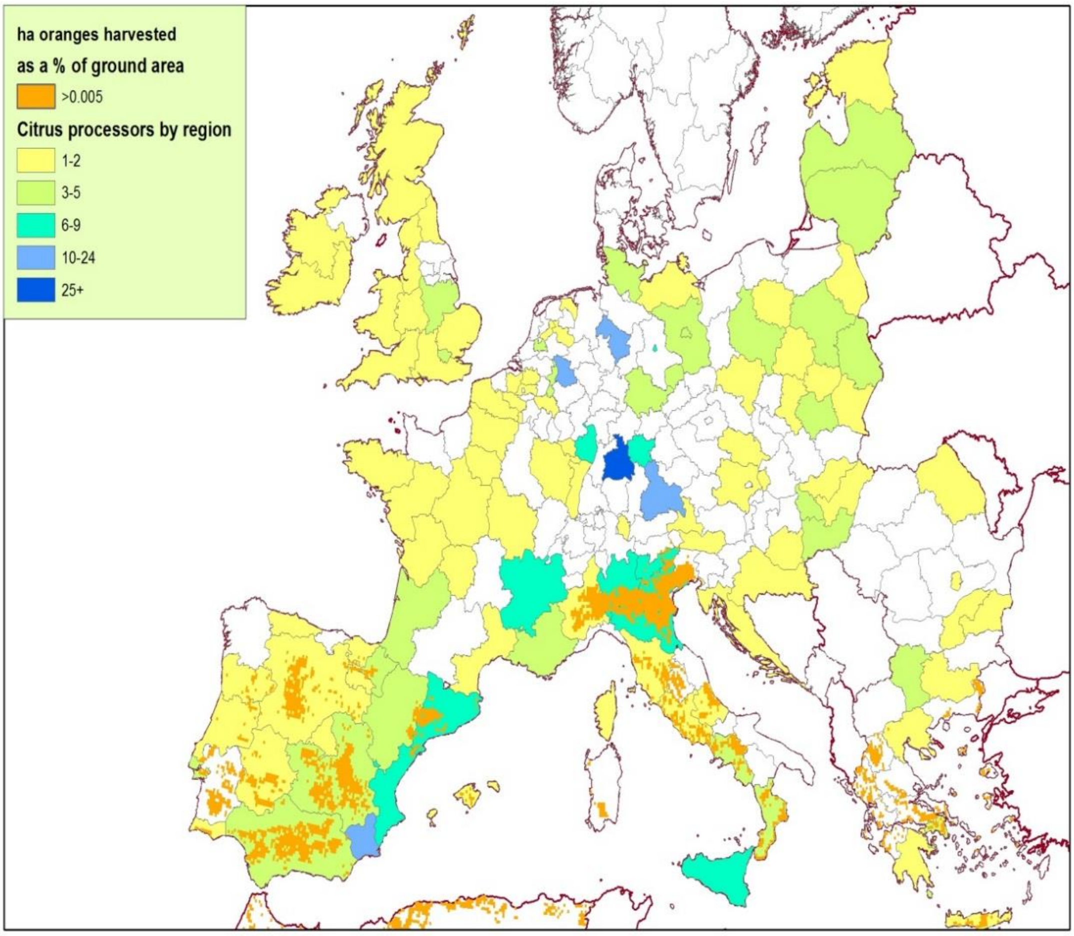
Business activities in the EU are classified by NACE (*Nomenclature statistique des activités économiques dans la Communauté européenne*) codes which align with the UN International Standard Industrial Classification (ISIC) system. The first two digits of the code represent the major industry sector to which a business belongs. The third and fourth digits describe the sub-classification of the business group and specialization, respectively. Statistics produced on the basis of NACE are comparable at European level and, in general, at world level (Eurostat European Commission, 2008).

The codes used to describe business activities are listed in the most recent version of the NACE codes in Eurostat European Commission (2008). Codes used to identify businesses involved in the processing and preserving of fruit and vegetables are listed in Table A.16.01. Around ten thousand businesses across the EU (27) are involved in the processing and preserving of fruit and vegetables, employing over 280,000 people.

Table A.16.01: NACE codes used to identify businesses involved in the processing and preserving of fruit and vegetables

Class	Division	Group	Class	Description
C				Manufacturing
	10			Manufacture of food products
		10.3		Processing and preserving of fruit and vegetables
			10.31	Processing and preserving of potatoes
			10.32	Manufacture of fruit and vegetable juice
			10.39	Other processing and preserving of fruit and vegetables

This data is not sufficiently detailed to identify the numbers of specialist citrus processors which is likely to comprise a very small proportion of the total companies involved in the processing of fruit and vegetables. Consequently, information on the number of specialist citrus processors was obtained from the on-line directory europages which provides numbers of citrus processors by NUTS2 distribution. Figures obtained from this site are likely to include only the larger processors which have registered with the site and are thus likely to represent a small sample of the actual number of companies engaged in this business. Figure A.16.01 shows the distribution of citrus processing sites at the NUTS2 scale (UK at NUTS1 level). Appendix provides that actual number of estimated processors for each NUTS2 region.



Source: www.europages.com Note: UK data at NUTS1

Figure A.16.01: Numbers of fruit processing sites in the EU at NUTS2 (estimate)

A.17 Waste streams

The waste product from citrus consumption and processing is the peel which is the part of the fruit infected by *X. citri* pv. *citri* . Therefore any inoculum escaping detection during harvesting and packing in the country of origin and inspection at the destination, which remains viable during transport and storage and is not destroyed during processing, presents a risk to local citrus producers.

Out of an estimated annual average 852,000 tonnes of sweet orange imported into the EU over the last five years, only 116,000 tonnes was from countries where *X. citri* pv. *citri* is endemic (Argentina, Australia, Brazil, US, Uruguay). Most of that tonnage from Uruguay, US and Australia will have been imported into countries where citrus production does not occur, but much of the Argentine and Brazilian exports goes to Spain. Some may have been imported directly into citrus producing EU countries such as Spain to cover a shortfall in local production required for juice processing, however there is also significant direct import of juice at very competitive prices from Brazil, in particular. Other consignments may have been imported into non-citrus producing countries and then transhipped to citrus producing countries. For example, in 2009, the Netherlands imported around 450,000 tonnes of sweet orange from various countries (including US, Argentina, Brazil and Uruguay) and re-exported almost 200,000 tonnes to other EU countries, including citrus-producing countries (EUROSTAT, online). Spain is known to import an unspecified quantity of fruit for processing from third countries during the six month period which falls outside the local harvest period. Imported S African citrus is the main source of fresh squeezed orange juice in the UK, France and Germany during summer months, according to Reuters (2014)[4]. Most (92%) of orange juice in the EU is imported as juice, processed abroad (Agrosynergie, 2006)[5].

Approximately half the weight of a fresh orange comprises the peel, pulp and rag suggesting that around 54,500 tonnes/year of peel from oranges imported from countries with *X. citri* pv. *citri* poses a potential risk to EU citrus production. It is likely that only a small quantity of this waste will end up either at processing plants in Spain, Italy, Portugal or Greece and so the potential risk to local citrus product will be very small.

On the assumption that imported sweet orange is allocated in line with the allocation of total supply, excluding that part of total supply which is exported, (Table A.14.02), approximately 18 and 82% of imported oranges, respectively, would be processed and marketed directly. Thus around 20,880 and 95,120 tonnes of imported oranges would go for processing or domestic sale, respectively.

Estimates of losses of fresh orange along the supply chain for Europe are unavailable. However, figures for supply chain losses for fresh citrus fruit along the supply chain have been reported by Terry *et al.* (2011). Terry et al. (2011) show a resource map for fresh citrus fruit indicating losses along the supply chain in the UK.

Estimated fresh citrus losses of 3% during post-import grading and inspection, 0.1-0.5% during packing and 2-2.5% during retail are reported along the supply chain to the point of sale (Terry et al., 2011). Additional losses, estimated at 110,000 tonnes, or 2.8% of the total supply (around 7,061 thousand tonnes) (Table A.14.02), for fresh orange for 2012, are the result of household waste after purchase (Quested, 2013). An EC DG-Environment report[6] in 2010 indicated significant variability in total food waste at various stages in the food supply chain, but this is not broken down to specific food groups, such as fruits. However, Terry et al. (2011)[7] estimates a very narrow range of retail waste for a range of fresh fruits and vegetables from 1% for onions to 4% for strawberries and 5% for avocados. Citrus and apples are in the central range at around 2.5% retail waste. Fresh fruit accounts for about 10% of total household food waste in the UK, and about 5% in Austria and Netherlands (Parfitt et al., 2011)[8]. While transport losses within the EU may vary, the level of distribution losses compared to other manufacturing, processing and household waste are very low, according to Lee and Willis (2010)[9].

Ultimately, approximately 50% of an orange is discarded as peel in households. This will either enter the general waste stream ending up as landfill or be used for composting along with the general food waste. Peel from oranges used in processing will either be used for cattle feed either directly or after extraction of useful chemicals. It is unlikely that *X. citri* pv. *citri* would survive during processing because of the chemical processes and heating required to produce the final product. The main risk in the processing operation would be the initial washing step (Figures A.15.01) before processing commences. Any bacteria in cankers on infected fruit are likely to enter the wash water and be discharged into waterways directly or after passing through a sewage treatment plant. It is not possible to either estimate the probable level of infection of oranges arriving at the processing plant or the potential of the pathogen to survive the washing procedure. No data on survival of xanthomonads in water could be found and it is not possible to predict their ability to survive for long periods in water.

[4] http://www.reuters.com/article/2014/04/29/eu-safrica-orangejuice-idUSL6N0NL3S320140429
[5] http://ec.europa.eu/agriculture/eval/reports/agrumes/sum_en.pdf
[6] http://ec.europa.eu/food/safety/food_waste/library/docs/bio_foodwaste_report_en.pdf
[7] http://www.wrap.org.uk/sites/files/wrap/Resource_Map_Fruit_and_Veg_final_6_june_2011.fc479c40.10854.pdf
[8] http://www.wrap.org.uk/sites/files/wrap/Waste%20arisings%20in%20the%20supply%20of%20food%20and%20drink%20toUK%20households,%20Nov%202011.pdf
[9] http://www.wrap.org.uk/sites/files/wrap/Waste%20arisings%20in%20the%20supply%20of%20food%20and%20drink%20toUK%20households,%20Nov%202011.pdf

A.18 Phenology of orange in Europe

The optimum temperature range for cultivation of sweet orange is between 25 and 30°C with the coldest month having a minimum of 13°C. No growth occurs below 13°C or above 38°C and in areas with a dry period of longer than three months irrigation is necessary.

Commercial citrus growing in Europe is confined to areas with Mediterranean climates (dry sub-tropical zone) with large diurnal temperature fluctuations (Davies, undated) and characterised by low rainfall (40-80 cms/annum), hot, dry days, cool nights and low humidity (<= 20%). In Europe Spain, Italy, Greece and Portugal are all characterised by these climatic conditions.

As with other deciduous fruit trees a cool (or dry) period is required to break dormancy and induce budburst, followed by a period of warming to promote anthesis. In temperate regions mature orange enters into an annual cycle of three growth flushes, in spring, summer and autumn, with only the first flush producing flowers and the following two purely vegetative shoots. Orange production is divided into nine developmental stages described by Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie (BBCH) codes (Meier, 2001). The codes for the stages in the annual citrus production cycle are shown in Figure A.18.01 and Table A.18.01.

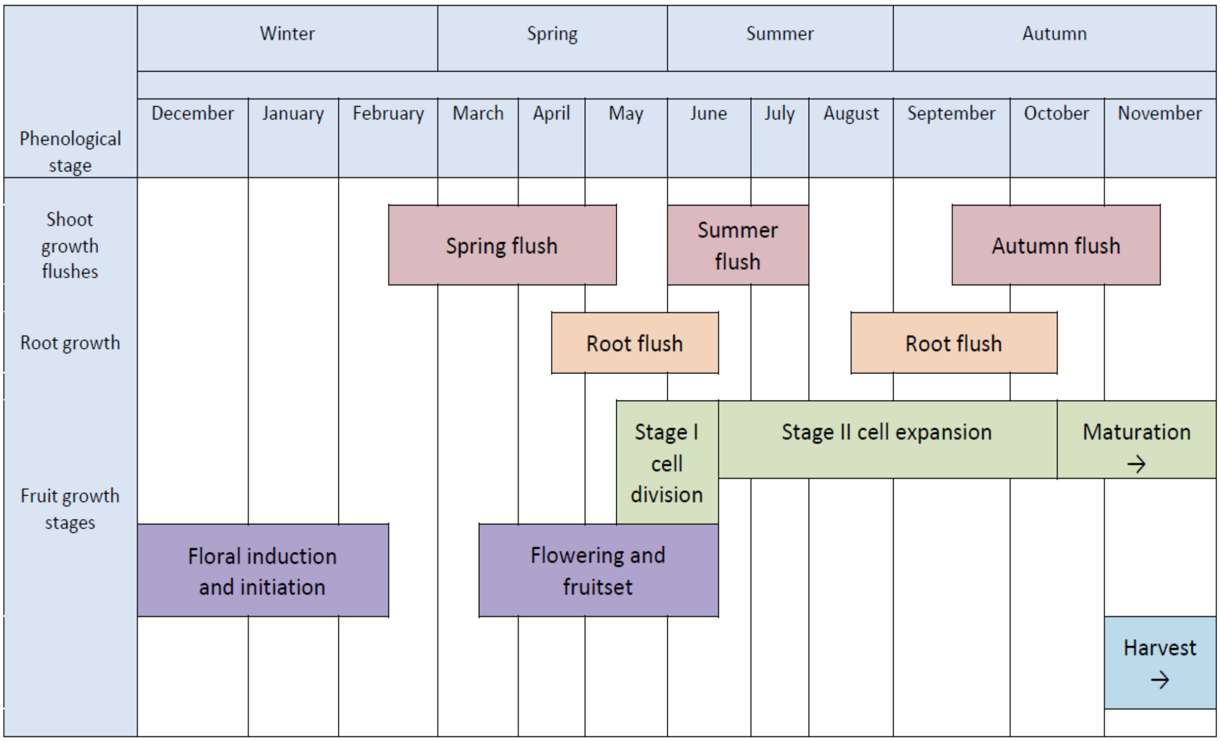


Figure A.18.01: Typical timing of seasonal vegetative and reproductive phonological events for citrus in the temperate Northern hemisphere

The exact timing and success of flowering and subsequent fruit development of sweet orange is dependent primarily on the local atmospheric temperatures of the preceding winter in order to fulfil the plant's chilling requirement, as well as the spring warming to induce anthesis. The rate of development of orange in response to local climatic conditions varies between different orange varieties which leads to different varieties being in different physiological stages of development at any time during the production season. This leads to an extended production season which in Spain extends from late October to mid-June.

Sweet orange is principally imported into the EU from countries where *X. citri* pv. *citri* is endemic outside the European harvest season (October to June). However, some imports take place throughout the year, presenting a risk of infection of local sweet orange and other citrus in European production areas.

At temperatures favourable for disease development (25-35°C), it is feasible that bacteria could be transferred from discarded diseased fruit close to domestically or commercially growing citrus. Infections could occur and spread rapidly at warm temperatures, with prolonged rain or overhead irrigation, when trees are in a susceptible stage of development for infection to occur. This is principally in the spring, summer and autumn growth flushes (Table A.18.01). Storms severe enough to cause damage to leaves and fruit facilitate spread of infection as does wounding by insects.

Table A.18.01. Annually recurrent reproductive events of citrus phenology, and their timing for the temperate Northern Hemisphere (after Meier, 2001; Connellan et al., 2010)

CITRUS REPRODUCTIVE PHENOLOGY (NORTHERN HEMISPHERE)			
Time of the Year	**Phenological Stage**	**BBCH Code**	**Description**
December - January	Floral induction and initiation	51	Bud differentiation and release from dormancy
February	Pre-bloom	55	Early indication of final crop load
March	Bud break	60	First buds start to open
March-May	Start of bloom Full bloom End of petal fall	61 65 69	5% of flowers open 50% of flowers open 80% petal drop
May-June	Fruit set	71	Fertilized flowers develop into fruit
May-July	Cell division	71	Mitosis
July	End of natural fruit drop	71	10-15mm fruitlets
July-October	Cell expansion	72	Final number of cells determined, cells increase in size
	Colour change	73	Colour change from pale green to light yellow
November-January	Fruit maturation	85	Internal maturity measured by the brix/acid ratio

Plant vegetation and fruit is less susceptible to infection outside the periodic growth flushes can still be infected when damaged. Resistance of leaves, stems and fruit also increases with tissue age (Stall *et al.*, 1982; Vernière *et al.*, 2003). Fruit also is not susceptible to infection in the absence of wounds when fully mature.

A.19 World distribution of *X. citri* pv. *Citri*

Table A.19.01. Distribution of *X. citri* pv. *Citri*

Africa	
Comoros; Present, widespread	Burkina Faso; Present, no details
Cote d'Ivoire; Present, no details	Congo, Democratic republic; Present, no details
Gabon; Present, no details	Ethiopia; Present, no details
Mali; Present, restricted distribution	Madagascar; Present, no details
Mayotte; Present, restricted distribution	Mauritius; Present, no details
Senegal; Present, restricted distribution	Reunion; Present, no details
Somalia; Present, few occurrences	Seychelles; Present, no details
	Tanzania; Present, restricted distribution
America	
Bolivia; Present, no details	Argentina; Present, restricted distribution
Paraguay; Present, widespread	Brazil; Present, restricted distribution
Uruguay; Present, restricted distribution	United States of America; Present, restricted distribution
	Virgin Islands (British) ; Present, no details
Asia	
Bangladesh; Present, restricted distribution	Afghanistan; Present, no details
China; Present, widespread	Cambodia; Present, no details
Cocos Islands;Present, no details	Christmas Island; Present, no details
Indonesia; Present, no details	India;Present, no details
Japan; Present, widespread	Iran;Present, restricted distribution
Korea, Republic; Present, no details	Korea Dem. People's Republic; Present, no details
Malaysia; Present, widespread	Lao; Present, no details
Myanmar; Present, no details	Maldives; Present, no details
Oman; Present, no details	Nepal; Present, no details
Philippines; Present, no details	Pakistan; Present, no details
Singapore; Present, no details	Saudi Arabia;Present, restricted distribution
Taiwan; Present, widespread	Sri Lanka;Present, no details
United Arab Emirates; Present, no details	Thailand; Present, no details

Yemen ; Present, restricted distribution	Viet Nam; Present, widespread
	Europe ; Absent
Oceania	
Guam; Present, no details	Fiji; Present, no details
Micronesia; Present, no details	Marshall Islands; Present, no details
Palau; Present, no details	Northern Mariana Islands; Present, no details
Solomon Islands; Present, few occurrences	Papua New Guinea; Present, no details

A.20 CODEX quality standard for orange

CODEX quality standard for oranges
CODEX STAN 245 Amended 2005, 2011. **CODEX STANDARD FOR ORANGES** **(CODEX STAN 245-2004)** 1. **DEFINITION OF PRODUCE** This Standard applies to commercial varieties of oranges grown from *Citrus sinensis* (L.) Osbeck, of the *Rutaceae* family, to be supplied fresh to the consumer, after preparation and packaging. Oranges for industrial processing are excluded. 2. **PROVISIONS CONCERNING QUALITY** 2.1 **MINIMUM REQUIREMENTS** In all classes, subject to the special provisions for each class and the tolerances allowed, the oranges must be: - whole; - sound, produce affected by rotting or deterioration such as to make it unfit for consumption is excluded; - clean, practically free of any visible foreign matter; - practically free of pests affecting the general appearance of the produce; - practically free of damage caused by pests; - free of abnormal external moisture, excluding condensation following removal from cold storage; - free of any foreign smell and/or taste; - free of damage caused by low and/or high temperatures; - free of damage caused by frost; - free of signs of internal shrivelling; - practically free of bruising and/or extensive healed-over cuts. 2.1.1 The oranges must have reached an appropriate degree of development and ripeness account being taken of the characteristics of the variety, the time of picking and the area in which they are grown. The development and condition of the oranges must be such as to enable them: - to withstand transport and handling; and - to arrive in satisfactory condition at the place of destination. Oranges satisfying these requirements may be "degreened". This treatment is permitted only if the other natural organoleptic characteristics are not modified. 2.2 **MATURITY CRITERIA** The maturity of oranges is defined by the following parameters: - Colouring;

- Minimum juice content, calculated in relation to the total weight of the fruit and after extraction of the juice by means of a hand press.

2.2.1 **Colouring**

The degree of colouring shall be such that, following normal development, the oranges reach their normal variety colour at their destination point, account being taken of the time of picking, the growing area and the duration of transport.

Colouring must be typical of the variety. Fruits with a light green colour are allowed, provided it does not exceed one-fifth of the total surface area of the fruit.

Oranges produced in areas with high air temperatures and high relative humidity conditions during the developing period can be of a green colour exceeding one fifth of the total surface area, provided they satisfy the criteria mentioned in Section 2.2.2 below.

2.2.2 **Minimum Juice Content**

- Blood oranges 30%
- Navels group 33%
- Other varieties 35%
- Varieties Mosambi, Sathgudi and Pacitan
with more than one-fifth green colour 33%
- Other varieties with more than one-fifth green colour 45%

2.3 **CLASSIFICATION**

Oranges are classified in three classes defined below:

2.3.1 **"Extra" Class**

Oranges in this class must be of superior quality. In shape, external appearance, development and colouring, they must be characteristic of the variety and/or commercial type. They must be free of defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package.

2.3.2 **Class I**

Oranges in this class must be of good quality. They must be characteristic of the variety and/or commercial type. The following slight defects, however, may be allowed, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package:

- slight defect in shape;
- slight defect in colouring;
- slight skin defects occurring during the formation of the fruit, such as silver scurfs, russets,etc.;
- slight healed defects due to a mechanical cause such as hail damage, rubbing, damage from handling, etc.

The defects must not, in any case, affect the pulp of the fruit.

2.3.3 **Class II**

This class includes oranges which do not qualify for inclusion in the higher classes, but satisfy the minimum requirements specified in Section 2.1 above. The following defects, however, may be allowed,
provided the oranges retain their essential characteristics as regards the quality, the keeping quality and presentation:

- defect in shape;
- defect in colouring;
- skin defects occurring during the formation of the fruit, such as silver scurfs, russets, etc.;
- healed defects due to a mechanical cause such as hail damage, rubbing, damage from handling, etc.;
- rough skin;
- superficial healed skin alterations;
- slight and partial detachment of the pericarp.

The defects must not, in any case, affect the pulp of the fruit.

3. **PROVISIONS CONCERNING SIZING**

Size is determined by the maximum diameter of the equatorial section of the fruit, in accordance with the following table:

Size Code	**Diameter (mm)**
0	92 – 110
1	87 – 100
2	84 – 96
3	81 – 92
4	77 – 88
5	73 – 84
6	70 – 80
7	67 – 76
8	64 – 73
9	62 – 70
10	60 – 68
11	58 – 66
12	56 – 63
13	53 – 60

Oranges of a diameter below 53 mm are excluded.
Oranges may be packed by count. In this case, provided the size uniformity required by the Standard is retained, the size range in the package may fall outside a single size code, but within two adjacent codes.
Uniformity in size is achieved by the above mentioned size scale, unless otherwise stated, as follows:
(i) for fruit arranged in regular layers in the package, including unit consumer packages, the maximum difference between the smallest and the largest fruit, within a single size code or, in the case of oranges packed by count, within two adjacent codes, must not exceed the following maxima:

Size Code Maximum difference between fruit in the same package in mm
0 to 2 11
3 to 6 9
7 to 13 7

(ii) for fruit not arranged in regular layers in packages and fruit in individual rigid packages for direct sale to the consumer, the difference between the smallest and the largest fruit in the same package must not exceed the range of the appropriate size grade in the size scale, or, in the case of oranges packed by count, the range in mm of one of the two adjacent codes concerned.
(iii) for fruit in bulk bins and fruit in individual non-rigid (nets, bags) packages for direct sale to the consumer, the maximum size difference between the smallest and the largest fruit in the same lot or package must not exceed the range obtained by grouping three consecutive sizes in the size scale.

4. **PROVISIONS CONCERNING TOLERANCES**
Tolerances in respect of quality and size shall be allowed in each package for produce not satisfying the requirements of the class indicated.

4.1 **QUALITY TOLERANCES**

4.1.1 **"Extra" Class**
Five percent by number or weight of oranges not satisfying the requirements of the class, but meeting those of Class I or, exceptionally, coming within the tolerances of that class.

4.1.2 **Class I**
Ten percent by number or weight of oranges not satisfying the requirements of the class, but meeting those of Class II or, exceptionally, coming within the tolerances of that class.

4.1.3 **Class II**
Ten percent by number or weight of oranges satisfying neither the requirements of the class nor the minimum requirements, with the exception of produce affected by rotting or any other deterioration rendering it unfit for consumption.
Within this tolerance, a maximum of 5% is allowed of fruit showing slight superficial unhealed damage, dry cuts or soft and shrivelled fruit.

4.2 **SIZE TOLERANCES**

For all classes, 10% by number or weight of oranges corresponding to the size immediately above and/or below that indicated on the package.
The 10% tolerance only applies to fruit whose diameter is not less than 50 mm.

5. **PROVISIONS CONCERNING PRESENTATION**

5.1 **UNIFORMITY**

The contents of each package must be uniform and contain only oranges of the same origin, variety and/or commercial type, quality and size, and appreciably of the same degree of ripeness and development.
The visible part of the contents of the package must be representative of the entire contents. In addition, uniformity of colouring is required for "Extra" Class.

5.2 **PACKAGING**

Oranges must be packed in such a way as to protect the produce properly. The materials used inside the package must be new1, clean, and of a quality such as to avoid causing any external or internal damage to the produce. The use of materials, particularly of paper or stamps bearing trade specifications is allowed, provided the printing or labelling has been done with non-toxic ink or glue.
Oranges shall be packed in each container in compliance with the Recommended International Code of Practice for Packaging and Transport of Fresh Fruits and Vegetables (CAC/RCP 44-1995).
1 For the purposes of this Standard, this includes recycled material of food-grade quality.

5.2.1 **Description of Containers**

The containers shall meet the quality, hygiene, ventilation and resistance characteristics to ensure suitable handling, shipping and preserving of the oranges. Packages must be free of all foreign matter and smell.

5.3 **PRESENTATION**

The oranges may be presented as follows:
(a) Arranged in regular layers in the package. This form of presentation is mandatory for "Extra" Class and optional for Classes I and II;
(b) Not arranged in packages. This type of presentation is only allowed for Class I and II;
(c) In individual packages for direct consumer sale of a weight less than 5 kg, either made up by number or by weight of fruit.

6. **MARKING OR LABELLING**

6.1 **CONSUMER PACKAGES**

In addition to the requirements of the Codex General Standard for the Labelling of Prepackaged Foods (CODEX STAN 1-1985), the following specific provisions apply:

6.1.1 **Nature of Produce**

If the produce is not visible from the outside, each package (or lot for produce presented in bulk) shall be labelled as to the name of the produce and may be labelled as to the name of the variety and/or commercial type.

6.2 **NON-RETAIL CONTAINERS**

Each package must bear the following particulars, in letters grouped on the same side, legibly and indelibly marked, and visible from the outside, or in the documents accompanying the shipment.

6.2.1 **Identification**

Name and address of exporter, packer and/or dispatcher. Identification code (optional)2.

6.2.2 **Nature of Produce**

Name of the produce if the contents are not visible from the outside. Name of the variety and/or commercial type (optional)3.

6.2.3 **Origin of Produce**

Country of origin and, optionally, district where grown or national, regional or local place name.

6.2.4 **Commercial Identification**

- Class;
- Size code for fruit presented in accordance with the size scale or the upper and the lower limiting size code in the case of three consecutive sizes of the size scale;
- Size code (or, when fruit packed by count fall under two adjacent codes, size codes or minimum and maximum diameter in mm) and number of fruit, in the case of fruit arranged in layers in the package;

2 The national legislation of a number of countries requires the explicit declaration of the name and address.
However, in the case where a code mark is used, the reference "packer and/or dispatcher (or equivalent abbreviations)" has to be indicated in close connection with the code mark.
3 The national legislation of a number of countries requires the explicit declaration of the variety.
- If appropriate, a statement indicating the use of preservatives;
- Net weight (optional).
6.2.5 **Official Inspection Mark (optional)**
7. **CONTAMINANTS**
7.1 The produce covered by this Standard shall comply with the maximum levels of the Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995).
7.2 The produce covered by this Standard shall comply with the maximum residue limits for pesticides established by the Codex Alimentarius Commission.
8. **HYGIENE**
8.1 It is recommended that the produce covered by the provisions of this Standard be prepared and handled in accordance with the appropriate sections of the Recommended International Code of Practice – General Principles of Food Hygiene (CAC/RCP 1-1969), Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53-2003), and other relevant Codex texts such as Codes of Hygienic Practice and Codes of Practice.
8.2 The produce should comply with any microbiological criteria established in accordance with the Principles for the Establishment and Application of Microbiological Criteria for Foods (CAC/GL 21-1997).

A.21 Network of intra-EU trade in sweet oranges

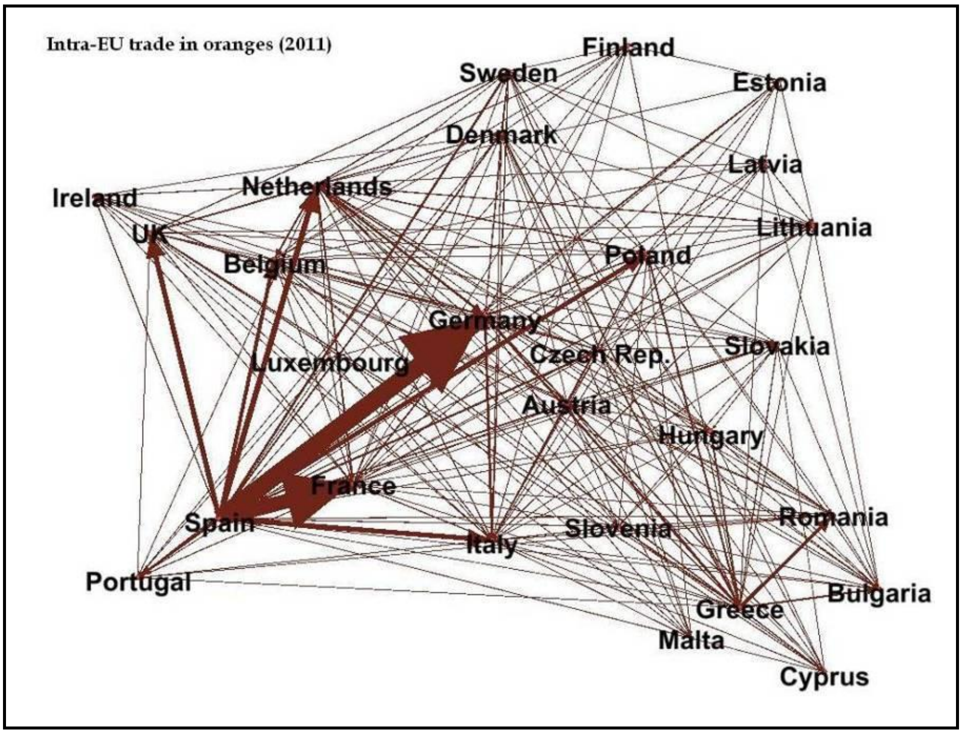


Figure A.21.01: Network visualization of the intra-EU trade in sweet oranges in 2011 (the weight of the links is proportional to trade volume) (EFSA, 2014)

Appendix B – Case study: Pome fruit (apples) from USA and Canada with potential infestation by *Cydia prunivora*

B.1 Introduction

The project had already selected the case study commodities and pests as shown in Table B.1.01.

Table B.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities and pests

Commodity	Pest	Common name	Case study countries
Pome fruit: Fresh apples	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit: Fresh plums	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus: Sweet oranges	*Xanthomonas citri citri*	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries).
Cereals: Wheat	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

To inform parameterization of the pathway models for each commodity, this report collects information on:

- the distribution of pests at pathway origin,
- exports and pathway regulations and pest survival,
- trans-shipments,
- commodity uses,
- commodity processing and waste management, and
- location of processors.

The information is used to provide the rationale for selecting the estimated values for several of the quantitative inputs required in the quantitative models describing the likelihood of pest entry via selected case study pathways on one of four commodity types (Table B.1.01). The report begins by examining the pest of concern (*Cydia prunivora*) for the apple commodity.

B.2 Occurrence of case study pest at origin (North America)

Cydia (=*Grapholita*) *prunivora*, the lesser apple worm, is widely distributed in North America (Mantey *et al.*, 2000). It is probably native to eastern North America and was first reported to attack apples in Canada in 1895 (Fletcher, 1898; cited in Mantey *et al.*, 2000). EPPO PQR (2014) and CABI CPC (2012) provide detailed sub-national distribution records of the pest showing which US States and Canadian Territories and Provinces the pest occurs in. Importantly *C. prunivora* occurs in the major apple producing and exporting areas of North America. However, the most significant Tortricid pests that infest apple fruit in North America are *Cydia pomonella* (codling moth) and *Grapholita molesta* (Oriental fruit moth) both or which occur widely in Europe and hence are not quarantine pests within the EU.

Whilst *C. pomonella* moth larvae are relatively large and feed to the core of apple fruit, *C. prunivora* larvae are smaller and feed below the surface of the skin of fruit causing surface blotches (Mantey *et al.*, 2000).

Chemical control methods used against *C. pomonella* also control *C. prunivora. Cydia prunivora* was not regarded as a problem in North America and hence relatively little studied until Japan made it a quarantine pest in 1991, disrupting apple exports (Mantey *et al*., 2000). As a consequence of the organisms increased importance once Japan had listed it as a quarantine pest, a number of research projects were commissioned in North America to examine the biology of *C. prunivora* in the early 1990s. Note that much American literature uses the synonym *Grapholita prunivora.*

In a study in four commercially managed apple orchards in Michigan, USA, 1991-1994, Krawczyk & Johnson (1996) reported no fruit with injury caused by *Grapholita* (=*Cydia*) *prunivora*. However, in abandoned (i.e. unmanaged) orchards, the pest caused up to 5% injuries.

In studies examining pest control methods in 16 commercial apple orchards in New York State between 2002 and 2005 Agnello *et al.* (2002 - 2005) reported fruit damage at harvest caused by internal Lepidoptera feeding was uniformly low. During the course of the study novel treatments were compared with standard grower practices which resulted in 99.73% to 99.98% of harvested fruit being free from damage by internal Lepidopteran feeders such as *C. pomonella*, *G. molesta* or *C. prunivora*. Depending on the treatment applied harvested fruit were found to be between 99.6% and 100% free from internal Lepidopteran feeders (Table 2). Although damage was not attributed to individual species, the text in the reports, and from related studies by Reissig *et al.* (2005), suggests that most damage was caused by *G. molesta* and *C. pomonella*. Hence only a proportion of infestation was caused by the case study pest relevant to the current report, *C. prunivora.*

B.3 Case study pest life cycle: Cydia prunivora

At 25^{o}C the life cycle is completed in around 26 days (range 22-30 days; Neven & Mantey, 2004). Eggs develop above a threshold temperature of 8.5^{o}C. Following oviposition approximately 62.7 degree days above 8.5C is required for egg hatch, thus at a constant 25C, eggs hatch after approximately to 3.8 days. There are four larval instars. There is considerable variation in the rate of development within instars. Adults emerge 22 to 30 days after egg laying.

B.4 Phenology of Cydia prunivora

Cydia prunivora overwinters as a mature larva in a cocoon in debris on the ground or in crevices in the trunks of host trees. There are normally two generations per year. In western New York State, USA, and in Ontario, Canada, pupation takes place in May and lasts 2-3 weeks. Adults start to emerge in late May and the moths are present throughout June. On the east of the USA in Oregon, adults are most abundant in August and September, although they can be found between May and October (Bai *et al*., 2000). A life cycle for *Cydia prunivora* is illustrated at http://www.oksir.org/lifecycle.asp

Eggs are laid singly on the upper surface of host leaves and on the young fruit. Larvae become fully grown over the latter half of July to early August. Many of these larvae complete their development on fruits that have fallen to the ground. Second-generation adults are on the wing in August. Individual larvae of the next generation develop over an extended period from late August to early October. Final instar larvae overwinter in cocoons within ground cover and in the trunks of host trees. Some overwintering larvae may be found in fallen apple fruits in October and later. The following spring larvae develop into pupae and adults of the first generation emerge to repeat the cycle.

B.5 Likelihood of infestation at harvest

Working in the north-eastern US between 2004 and 2007, Peck *et al*., (2010) reported mean annual damage to apple fruit due to internal Lepidopteran feeding, produced in conventional production systems, as being between 0.2% (2004) and 0.9% (2005). In 2006 damage was 0.3% and in 2007 damage was 0.4%. This was regarded as normal variation for the region.

Table B.5.01: Mean % fruit damaged by internal Lepidoptera (a proportion of which may be *C. prunivora*)

Year / Treatment	2002	2003	2004	2005
Pheromones + "reduced risk pesticides"	0.33	0.02	0.06	0.03
"Reduced risk pesticides"	0.34	0.40	0.14	0.00
Grower standard	0.27	0.11	0.02	0.02
Notes	8 of 16 orchards had some damage	6 of 16 orchards had some damage	7 of 16 orchards had some damage.	2 of 16 orchards had some damage. Maximum damage was 0.07%
Reference	Agnello *et al.* 2002	Agnello *et al.* 2003	Agnello *et al.* 2004	Agnello *et al.* 2005

From reviewing North American literature, evidence suggests that the percentage of harvested commercial apple fruit that is likely to be infested with lepidopteran larvae at harvest is variable, but is usually less than 0.5%. Fruit from organic orchards may have higher levels of infestation (Peck *et al.*, 2010) although the area of organic apple production is the USA is relatively small.

The area of commercial apple production in USA is 328,000 acres[10] (approximately 132,700ha) whilst the area of organic apple production in USA (2008 data) was 17,626 acres[11] (approximately 7,130 ha) or 5.4% of apple production area.

Expressed as a weight of infested apples, we need to convert individual apples into kg. EU marketing regulations (Anon., 2011) note that apples must weigh at least 60g but can exceed 300g. Apples must be packaged in groups of similar weight individuals according to the following:

For "Extra" Class and Classes I and II apples packed in rows and layers are grouped into categories of 70 - 90g, 91 – 135g, 136 – 200g, 201 – 300g or >300g. For Class I fruit packed loose the categories are 70 – 135g, 136 – 300g and > 300g. Based on these categories, it is reasonable to estimate that imported apples will weigh a minimum of 70g, most likely around 150g and have a maximum weight of over 300g. An import of 100,000 apples could therefore range in weight from 7 tonnes (minimum) to over 30 tonnes (maximum). Within this 22 infested apples could weigh between 1.54 kg (min) and over 6.6 kg (max).

[10] http://www.usapple.org/index.php?option=com_content&view=article&id=179&Itemid=285
[11] http://www.agmrc.org/commodities__products/fruits/apples/commodity-apple-profile/

Contribution to model input parameters

Likelihood of infestation at harvest

In studies by Agnello *et al.* over 4 years, at least 50% of orchards studied had no damage from internal Lepidoptera each year (mean value over 4 years is 74% ((8/16)+(6/16+(7/16)+(2/16))/4). Standard grower practice resulted in mean infestation of 0.11% ((0.27+0.11+0.02+0.02)/4).

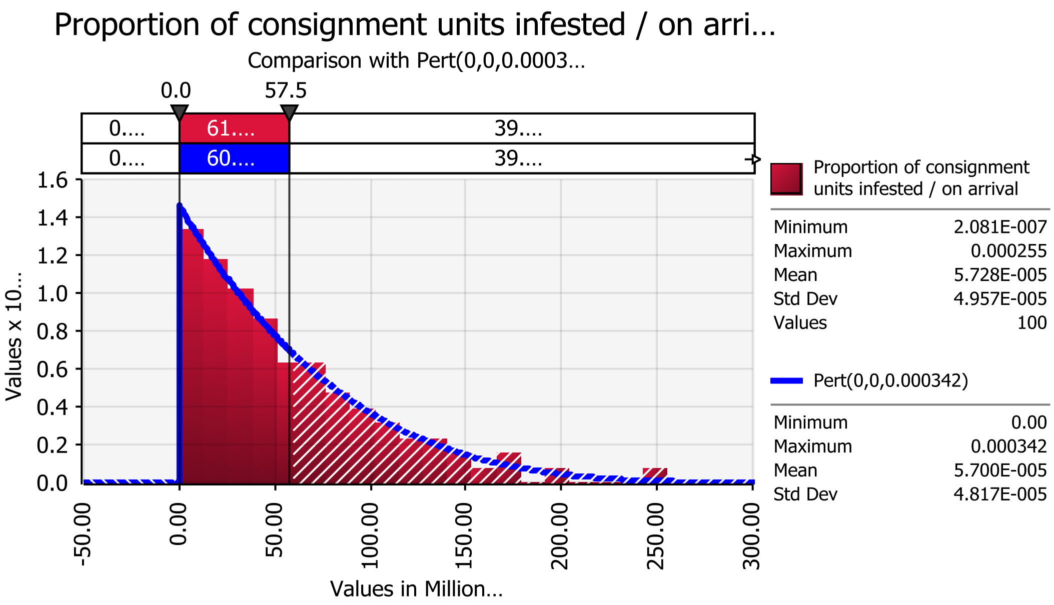
Hence possible input parameter has a probability distribution function (pdf) with 50% (or 74%) being 0 and the remaining % having a mean of 0.11%

However, this would represent the likelihood of a harvested apple being infested by one of three species. Two of which are more abundant than the case study pest.

If all Lepidoptera were equally abundant one could divide the above likelihood by 3. (0.11% / 3 = 0.0366%). This would still overestimate the likelihood of infestation by *C. prunivora*. Assuming only 20% of any infestation was due to *C. prunivora* would seem reasonable, hence divide 0.11% by 5 (0.11/5= 0.022%).

74% with infestation of zero and 26% with average infestation of 0.022% gives a mean infestation rate of (0.74 x 0) + (0.26 x 0.00022) = 0.0000572 (this is the <u>mean</u> not the most likely).

Note that Minimum is zero and most likely is also zero. The max was 0.27 /500 = 0.00054. This may be a bit extreme and a lower max of 0.000342 also gives a distribution mean close to the calculated value. This gives the graph below, in which about 60% of the distribution fall below the calculated mean



This is not the same as 70% zero but then arguably, 'no damage' actually means no damage detected, so very low non-zero values may be more realistic.

B.6 Harvesting, sorting and storing apples

Apples should be hand-picked by trained pickers that can recognise and pick only marketable fruit and who avoid inferior fruit. Apples infested with *C. prunivora* show symptoms that are usually visible to the naked eye (CABI, CPC 2012) and hence will avoid being harvested. Efficient producers do the absolute minimum of sorting once the fruit is picked as this is both inefficient and costly and can increase bruising tremendously. Fruit quality is preserved if fruit is immediately cooled after harvest (Wilson, 2009). Size grading is generally performed mechanically. If grading is performed by hand, gaging rings or gaging boards are used. Dessert apples are divided into three quality classes: extra (minimum diameter 65 mm), I (minimum diameter 60 mm) and II (minimum diameter 55 mm) (GDV, 2014).

Apples may be successfully kept in storage for a few weeks to several months, almost up to a year. Bates *et al.* (2001) report that there are three types of storage buildings for apples: air cooled storage, mechanically refrigerated storage and refrigerated storage with controlled-atmosphere. Only the highest quality dessert apples destined for the fresh market are placed in controlled-atmosphere storage which is expensive to operate. To maintain their high quality, it is extremely important that apples are picked at the proper stage of maturity (Bates *et al.,* 2001). For long-term storage in a controlled atmosphere with low oxygen, fruit is usually picked slightly less mature to maximize storage success (Wilson, 2009). Depending on the cultivar, apples stored in cold storage are held at between 1°C and 4°C. If stored within controlled atmospheric conditions, the modified atmosphere will consist of 2 to 3% oxygen and 1 to 4% carbon dioxide, and at a reduced temperature although the exact specifications are adjusted to the cultivar being stored (GDV, 2014). Apples can maintain quality under these conditions for 4 to 6 months.

Apples can be stored for several months in controlled-atmosphere chambers. High concentrations of CO2 are used in the air to prevent ethylene concentrations from rising which would induce ripening. When removed from storage ripening continues (Anon., 2007). Some apple varieties can be stored for up to a year without significant degradation (Yepsen, 1994; Food Science Australia, 2005).

Most apples for processing result from discards of the fresh fruit harvest and collecting apples for processing is mainly thought of as a salvage operation. The amount of apples available to process is largely dependent on the size of the fresh market harvest and its quality. Consequently, processing apples are harvested and stored in the same manner as premium, fresh market apples (Bates *et al.,* 2001).

B.7 Apples for export

Within EU phytosanitary legislation, apple fruit from outside the EU are regulated articles subject to the EC Plant Health Directive (Anon., 2000). The EC Plant Health Directive uses the synonym *Enarmonia prunivora* Walsh, in Annex II/ A I for *Cydia prunivora*. This means that the organism is regarded as a harmful organism whose introduction into, and spread within, all Member States shall be banned if present on plants of *Crataegus* L., *Malus* Mill., *Photinia* Ldl., *Prunus* L. and *Rosa* L., intended for planting, other than seeds, and fruit of *Malus* Mill. and *Prunus* L., originating in non- European countries.

Before export, apple fruit from Third Countries must be inspected and found free of quarantine pests, specifically *Grapholita packardi* (cherry fruit worm), *Rhagoletis pomonella* (apple maggot), *Tachypterellus quadrigibbus* (apple curculio) and *Monilinia fructiciola* (brown rot). Interestingly *Enarmonia* (=*Cydia*) *prunivora* is not specifically mentioned although, as a quarantine pest, apple fruit would still have to be found free from it in order to satisfy export to the EU. If consignments are free from quarantine pests, then a phytosanitary certificate can be issued for export to the EU. As noted by GDV (2014) the quarantine regulations of the country of destination (in this case the EU) must be complied with and a phytosanitary certificate will be required for apples from the USA or Canada (or any other Third Country) with the enclosed with the shipping documents.

ISPM No. 31 on sampling of consignments, provides guidance as to how many lots (e.g. boxes of fruit), are to be sampled within a consignment depending on the size of the consignment (i.e. how many lots), the degree of pest infestation (5%, 2%, 1%, 0.5% and 0.1%) and the level of confidence required (80%, 90%, 95% or 99%). Sampling size increases as the level of infestation lowers and the confidence required increases.

Imported (and home produced) fruit and vegetables are subject to EU Marketing Standards which align with United Nations Economic Commission for Europe (UNECE) standards. Specific European Union marketing standards exist for apples and pears. The standards may be found in EU Commission Regulation 543/2011 and UNECE (2013). Freshfell Europe (2011) provides a summary of EU marketing standards for apple. In summary, fresh apples are required to be checked for conformity with EU marketing standards for quality and labelling. Apples must be "practically free from pests". "Practically free" is a recognised phytosanitary term used by IPPC and defined in ISPM No. 5 as …"*Of a consignment, field or place of production, without pests (or a specific pest) in numbers or quantities in excess of those that can be expected to result from, and be consistent with, good cultural and handling practices employed in the production and marketing of the commodity*". Such quality checks in an exporting country could lead to apples being rejected for export to the EU as a conformity certificate is required for all fresh produce shipments destined for the fresh market.

Contribution to model input parameters

Likelihood of avoiding detection during harvest and export checks

No studies have been found that quantify the likelihood of pickers detecting infested fruit but apples infested with *C. prunivora* show symptoms that are usually visible to the naked eye (CABI, CPC 2012) and hence will avoid harvesting them for export.

Conclusion: An estimate of the likelihood of infested fruit escaping detection and proceeding along the pathway is needed. Given trained pickers are used, fruit is then graded then inspected by NPPO officials to certify fruit meets export quality, and all the while symptoms are visible to the naked eye, is it reasonable to assume that only infestation at most below 0.5% remains undetected.

Hence assuming mean infestation was 0.022%, export checks do not reduce the level of infestation (to detect 0.1% infestation with 95% confidence, 950 of 1000 lots would need to be sampled!)

B.8 Shipping apples

Apples are shipped at the preclimacteric stage (tree or picking ripe). Apples are transportable if free from spoilage, damage, bruises and abnormal moisture. In addition, they must be practically free from diseases and pests. They may be stored for up to 6 months, depending on variety and degree of ripeness. Where controlled atmosphere transport is used, transport and storage duration may be extended to approx. 8 months. Apples are transported in crates and cartons. Jointed boxes are made from resin-free wood (standard softwood boxes), to prevent odour tainting. Package weight and dimensions are generally very variable (GDV, 2014).

Once packed, apples are transported via ship, aircraft, truck and rail. During transport, apples need cool, dry and good ventilation. A written cooling order must be obtained from the consignor before loading is begun. This order must always be complied with during the entire transport chain (GDV, 2014). The temperature at which apples are shipped varies according to apple variety (Table B.8.01) (Anon., 2006).

Table B.8.01: Transport conditions for fresh apples (Source: Anon., 2006)

Apple type	Maximum storage, transit and shelf life (days)	Optimum transit temperature (°C)	Relative humidity
Non-chill sensitive varieties	90-240	-1.1 to +1.0	90-95%
Chill sensitive varieties	35-45	+1.5 to 4.5	90-95%

B.9 Survival of case study pest during cold storage and shipping

56 days cold storage (2.0 ± 0.2°C) of apples infested with *C. prunivora* eggs at three stages of development resulted in complete mortality (Neven, 2004). Time-mortality responses for the three developmental stages of eggs are and shown below (Table B.9.01).

Table B.9.01: Time–mortality response of three egg stages of *C. prunivora*, oviposited on apple and exposed to low temperatures (2.0 ± 0.2°C) Source: Neven (2004)

Egg stage	N	LT_{90} (95% FL)	LT_{99} (95% FL)
1	3,307	23.2 (23.1 - 23.2)	39.4 (39.3 – 39.6)
2	5,226	20.4 (20.4 - 20.5)	44.2 (44.1 – 44.4)
3	4,255	24.8 (24.7 - 24.8)	51.9 (51.8 – 52.1)

Cold treatment of at least 55 days at 2.0 ± 0.2°C, an accepted regime to control *C. pomonella* eggs for postharvest control of codling moth on apples destined for export markets (Moffitt, 1988; Hansen, 2002), should be an effective treatment for postharvest control of *C. prunivora* eggs on apples (Neven, 2004).

Neven (2004) also reported the results of time-mortality responses by *C. prunivora* larvae (Table B.9.02)

Table B.9.02: Time–mortality response of *C. prunivora* larval instars developing in apple and exposed to low temperatures (2.0 ± 0.2°C) Source: Neven (2004)

Larval instar	N	LT_{90} (95% FL)	LT_{99} (95% FL)
1st	1,129	11.2 (11.1 – 11.4)	46.0 (44.8 – 47.3)
2nd	1,414	37.3 (37.2 – 37.5)	62.4 (61.9 – 62.8)
3rd	743	37.0 (37.7 – 38.4)	56.5 (55.7 – 57.3)
4th	1,078	71.5 (70.2 – 72.9)	235.7 (226.5 – 245.7)

In discussing her results, Neven (2004) suggests that *C. prunivora* larvae are more cold tolerant than larvae of *C. pomonella*.

Assuming that apples are shipped using cold storage, 100% of *C. prunivora* eggs on apples held in cold storage for 55 days will suffer mortality (Table A2.9.01). 1st, 2nd and 3rd instar larvae held in cold storage for 55 days will also suffer great mortality (Table A2.9.02). However, the duration that North American apples are held in cold storage for, before reaching Europe, is unknown. Following harvest one imagines there will be at least 2 or 3 days required before being loaded into a shipping container. Container-ships can cross the Atlantic in 12 to 15 days. There is also going to be at least 2 or 3 days required in Europe before emerging from storage. Thus the minimum time in cold storage is assumed to be 16 days, but apples are probably held in store for much longer as they store very well for extended periods. It is not unreasonable to assume that apple varieties that are not sensitive to chilling will be in cold storage for 90 days (Table A2.8.01), sufficient to kill all 1st to 3rd instar larvae and 90% of 4th instar larvae.

Contribution to model input parameters

An estimate of the likelihood of infested fruit remaining infested after shipping is needed. A conservative estimate would be to assume apples are in cold storage for 40 days, during which 99% of stage 1 eggs will suffer mortality and at least 90% of stage 2 and stage 3 eggs will suffer mortality (Table A2.9.01). More than 90% of eggs that hatch will die as 1st instar larvae (Table A2.9.02). 90% of 2nd and 3rd instar larvae already in the apple fruit will also die after 40 days in cold storage.

Conclusion: A conservative estimate is that 90% of fruit that were infested remain infested after 40 days.

B.10 Export of apples from USA and Canada

FAO Statistics[12] indicate that apple exports from the USA to the EU have been in decline, both in real terms, and as a percentage of all apple exports e.g. for the four most recent years for which data are available (2008 – 2011), US apple exports fell from 40,068 tonnes in 2008 (5.1% of US apple exports) to 11,598 tonnes in 2011 (1.2% of US apple exports that year). Over the same period, Canadian apple exports fell from 2,742 tonnes (6.4% of CA apple exports) to 1,593 tonnes (also 6.4% of apple exports in 2011). Eurostat showed showed a further decline in imports from the USA and Canada in 2014 at 9,005 and 180 tonnes, respectively.

So as to inhibit the introduction of harmful organisms, the EU requires that 100% of imported consignments of many plant products undergo phytosanitary inspection upon arrival in the EU unless the plant products qualify for reduced inspection levels. US apples are eligible for a reduced level of inspection. Work to justify reduced inspection began in 2004. Dossiers were prepared that examined the previous three years trading history of specific commodities with the volume of commodity and inspection record being taken into account, in addition the quarantine pests potentially carried on the pathway were also taken into account. Appendix 1 shows the dossier prepared for apples from the USA. To qualify for reduced inspections, an average of at least 200 consignments had to be shipped into the EU each year over the previous 3 years.

At a European Commission Plant Health Working Group on Reduced Plant Health Checks meeting (June 2014) it was agreed that the inspection of consignments of apples from USA should remain at 50%. Thus each EU Member State must inspect between 50% and 100% of the apple consignments imported from the USA each year. Due to the low level of apple consignments from Canada, Canadian apples are not subject to a reduced rate of inspection and 100% of Canadian apple consignments must be inspected.

Imported apples are also subject to EU Marketing Standards. Specific European Union marketing standards exist for apples and pears. The standards may be found in EU Commission Regulation 543/2011. Freshfell Europe (2011) provides a summary of EU marketing standards for apple. Fresh apples are required to be checked for conformity with EU marketing standards for quality and labelling. Apples must be "practically free from pests". Such quality checks could lead to apples being rejected for import to the EU. A conformity certificate is required for all fresh produce shipments destined for the fresh market. Importers can obtain these certificates at the point of import.

B.11 International trade statistics

Goods that are imported (and exported) have to be declared for customs duty purposes. Goods, including imported fruit, are declared using a numerical coding system. The World Customs Organization operates a global coding system referred to as the Harmonized System (HS). Within Europe the EU follows the HS system but also includes further subdivisions, hence the system within the EU has a different name and is referred to as Combined Nomenclature (CN). CN codes comprise of up to eight digits and a text description. Appendix 2 lists the 28 categories in which fresh apples can be described. Apart from a few major products, international trade classifications do not provide a detailed classification of processed products according to the primary commodity used in its preparation, thus only fresh imported apple fruit can be identified using CN codes.

B.12 Seasonality of apple imports from North America

Traditionally apples from Canada have been available in Europe all year round (FPJ, 2010) although there are seasonal peaks and troughs (see Eurostat trade data) and not all varieties are available during all months (Table B.12.01). For example, cv Paula Red and cv Gala have short seasons of 2 months (August & September and September & October respectively), whilst cv Spartan is available 11 months of the year, i.e. all months except August (FPJ, 2010).

[12] http://faostat3.fao.org/download/T/*/E

Table B.12.01: Availability of Canadian apple varieties through the year (Source: FPJ 2010)

Apple variety	J	F	M	A	M	J	J	A	S	O	N	D
Ambrosia									✓	✓	✓	✓
Empire	✓	✓	✓	✓	✓	✓				✓	✓	✓
Gala									✓	✓		
Golden Delicious	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Honeycrisp										✓	✓	✓
Idared	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Jonagold	✓	✓	✓							✓	✓	✓
McIntosh Red	✓	✓	✓						✓	✓	✓	✓
Paula Red								✓	✓			
Red Delicious	✓	✓	✓	✓	✓	✓				✓	✓	✓
Spartan	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓

The seasonality of apples from the USA is similar to that from Canada, although there are a greater range of varieties, some of which are available 12 months of the year (Table B.12.02).

Table B.12.02: Availability of apple varieties from the USA through the year (Source: FPJ 2010)

Apple variety	J	F	M	A	M	J	J	A	S	O	N	D
Braeburn	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Cameo	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Cripps Pink	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Criterion	✓	✓	✓	✓	✓	✓				✓	✓	✓
Elstar	✓	✓	✓						✓	✓	✓	✓
Empire	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fuji	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Gala	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Ginger Gold							✓	✓				
Golden Delicious	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Granny Smith	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Honeycrisp	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Jonagold	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Jonathan	✓	✓	✓	✓					✓	✓	✓	✓
McIntosh Red	✓	✓	✓	✓	✓				✓	✓	✓	✓
Newton Pippin									✓	✓	✓	✓

Pink Lady	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Red Delicious	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rome Beauty	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Spartan	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Winesap	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

B.13 Consignment sizes

Whilst it is relatively straight forwards to collect statistics regarding import volumes, the size of individual consignments is not readily available. However, for consignments that are inspected and generate a notification of non-compliance on Europhyt, a web-based network specifically concerned with plant health information operated by the European Commission and Member States, an indication of consignment size is available.

All records regarding any notification of non-compliance for imports of fresh apples January 1998 – November 2014 were extracted from EUROPHYT. Over this period there were 193 records associated with apples imported from 19 different Third countries (Argentina, Brazil, Canada, Chile, China, Iran, Japan, Korea, Lebanon, New Zealand, Pakistan, South Africa, Syria, Thailand, Tunisia, Turkey, United States of America, Uruguay and Vietnam). Of the 193 records, 185 provided information regarding the consignment weight in kg. Where the weight was not expressed in kg, units such as the number of boxes were given. Figure A2.13.01 shows the frequency distribution of consignment size for apple imports 1998-2014.

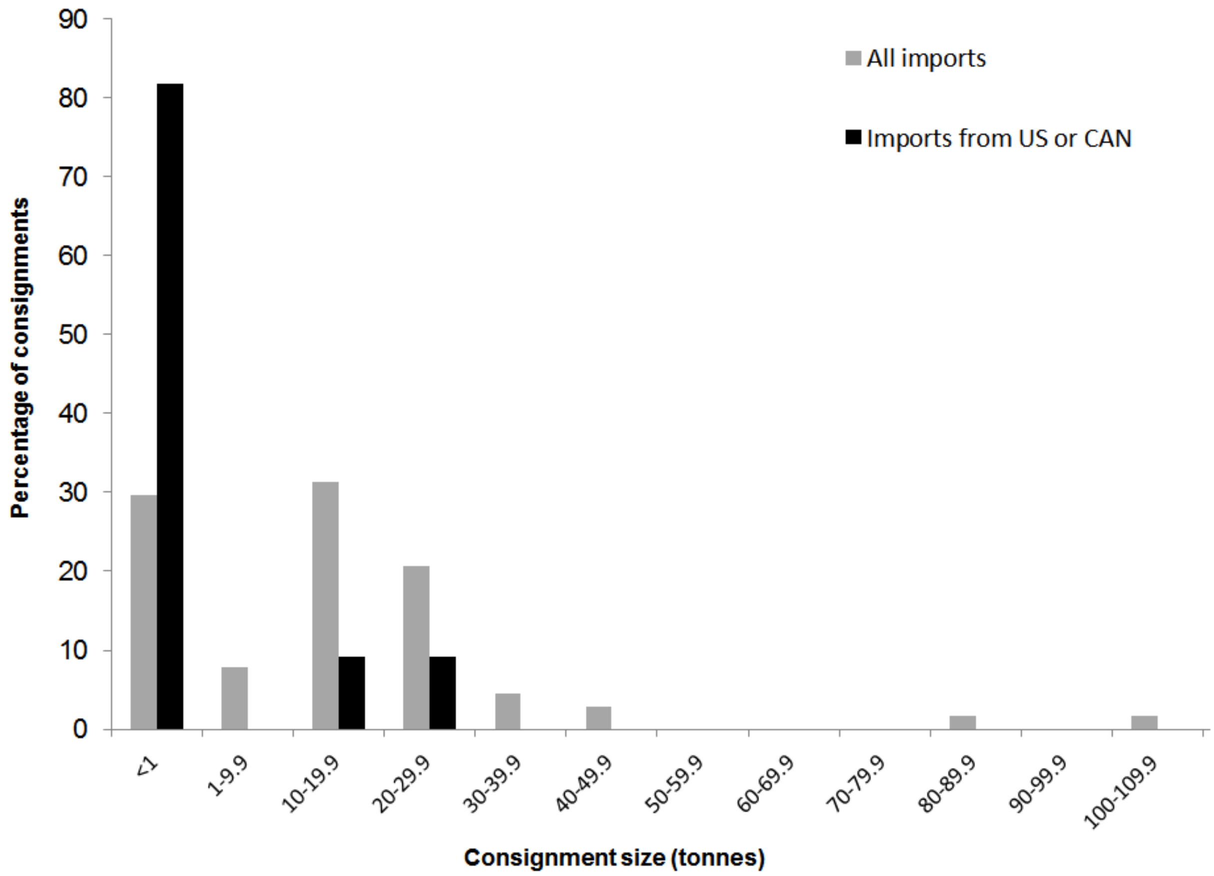


Figure B.13.01: Frequency distribution of consignment size of apple (fresh fruit) imports into the EU (Data derived from Europhy notifications of non-complance Jan 1998 – Dec 2014). N = 181 (all sources). Consignments from USA or Canada also shown (black columns) (n = 11)

Table B.13.01 shows the frequency of consignment sizes in more detail.

Table B.13.01: Frequency of apple fruit consignment size

Consignment size (tonnes)	Frequency of consignment size all Third Countries (%)	Frequency of consignment size USA and Canada (%)
<1	29.6	81.8
1 - 9.9	7.8	0.0
10 - 19.9	31.3	9.1
20 - 29.9	20.7	9.1
30 - 39.9	4.5	-
40 - 49.9	2.8	-
50 - 59.9	-	-
60 - 69.9	-	-
70 - 79.9	-	-

80 - 89.9	1.7	-
90 - 99.9	-	-
100 - 109.9	1.7	-

Of note, imports of apples from North America (Canada or USA) tend to be smaller than the consignments from other Third Countries. Over 80% of apple consignments from USA and Canada are less than 1 tonne whereas more than over 50% of apple consignments from Third countries are between 10 and 30 tonnes (Table B.13.01).

B.14 EU notifications of non-compliance on apples from North America

An examination of Europhyt did not reveal any interceptions of the case study pest, *C. prunivora*, between January 1998 and November 2014. Nevertheless there have been notifications of non-compliance registered on Europhyt in relation to apple fruit from USA or Canada (Table B.14.01). All infringements related to documentary checks and no pests have been reported.

Table B.14.01: Europhyt notifications of non-compliance of *Malus* spp. (fresh fruit) from USA or Canada

Date	EU MS	From	Transport	Reason for non-compliance	Quantity	unit
11/02/2000	DK	CA	Air	Phytosanitary certificate absent	18,000	kg
07/07/2000	PT	CA	Unknown	Phytosanitary certificate absent	4	NMB
14/09/2000	PT	USA	Unknown	Phytosanitary certificate absent	5	kg
20/11/2006	UK	USA	Air	Phytosanitary certificate absent	1	Box
20/12/2006	UK	USA	Air	Phytosanitary certificate absent	1	Box
24/07/2008	ES	USA	Sea	Incorrect identity declared on documents	200	kg
15/04/2011	UK	USA	Sea	Phytosanitary certificate absent	1.8	kg
05/12/2011	PT	CA	Passenger baggage	Phytosanitary certificate absent	3.6	kg
17/06/2013	UK	US	Air	Phytosanitary certificate absent	1	Pce
13/12/2013	UK	US	Air	Phytosanitary certificate absent	9	kg
08/09/2014	UK	CA	Air	Phytosanitary certificate absent	10	kg

Noting that several of the interceptions were on very small amounts of apples (10kg or less), it is possible that these interceptions occurred during inspections of passenger luggage, with members of the public carrying fresh fruit for personal consumption rather than commercial consignments. Nevertheless, at least two interceptions above do appear to be commercial given that the volumes were 18,000 kg and 200kg, well above what could be expected to be considered for personal use.

B.15 Pest interceptions

Although *C. prunivora* has not (yet) been intercepted by any EU Member State, larvae of Tortricidae have been intercepted in apples from the USA entering Mexico (Barcenas *et al.*, 2005) which is why Barcenas *et al.* developed a DNA diagnostic method to differentiate between four internal apple-feeding lepidopteran larvae. This indicates that international movement of fresh apples can provide a pathway for the movement of Tortricidae as larvae.

B.16 The current status of international trade in apples from USA and Canada

In March 2014 US media reported that the European Union banned the import of apples and other fruit from the USA and Canada, due to excessive residues of diphenylamine, commonly known as DPA, exceeding a threshold of 0.1ppm. The US media noted that the measure is to be reviewed in two years (2016) when it could be lowered or increased at that time based on monitoring data[13, 14]. However, no information to support the US media claim of an import ban was found on any EC or EU MS website.

B.17 Destination of imported apples within the EU

The Europhyt data base of notifications of non-compliance (referred to above) record the country of origin, point of arrival into the EU and final destination, for each consignment within the database. There were 193 records of notifications (from all countries) concerning apples between January 1998 and November 2014. The apples were imported from 19 different Third countries (listed previously). Of 193 records, 44 (22.8% of 193) were destined for a country other than that in which the consignment first arrived. Hence, for the majority of apple consignments (149 of 193: 77.2%), the country into which they arrive into the EU is also the intended country of final destination.

B.18 Transhipment of apples within the EU

Of the 44 shipments that were "trans-shipped", the majority (38 of 44 = 86.4%) were routed via the Netherlands and were destined for Belgium, France or Germany (Table A2.18.01). Three consignments arrived in Italy from Chile but were destined for Turkey (outside the EU). Three other consignments first arrived in France, one was destined for Reunion (a French DOM and hence outside mainland Europe), the two others were destined for the Netherlands.

Examination of this data reveals that between 1998 and 2014, no consignments of apples from North America were transhipped within the EU.

Table B.18.01: Numbers of apple consignments trans-shipped through the Netherlands, 1998-2014, which resulted in a notification of non-compliance. Third country origin and final EU destination are shown (Source: EUROPHYT data)

EU destination / Third country Origin	Belgium	France	Germany	Totals
Argentina	13	-	1	14
Chile	12	4	-	16
South Africa	6	-	-	6
China	-	-	1	1
Brazil	-	-	1	1
Totals	31	4	3	38

Of the 40 consignments trans-shipped within the EU (38 via NL, 2 via FR), the majority were consignments under 20 tonnes (25 of 40 = 62.5%; Table B.18.02).

[13] http://globalnews.ca/news/1295658/enjoying-that-apple-it-could-be-toxic-european-union-believes/

[14] http://qz.com/204218/europes-us-apple-ban-is-making-americans-notice-just-how-lax-us-environmental-safety-standards-really-are/

Table B.18.02: Frequency of consignment size of apples, trans-shipped within the EU

Consignment size (tonnes)	Number of consignments	Frequency (%)
<1	1	2.5
1 - 4.9	1	2.5
5 - 9.9	0	0.0
10 - 14.9	14	35.0
15 - 19.9	9	22.5
20 - 24.9	15	37.5
>25	0	0
sum	40	100.0

B.19 Apple uses

Apples are more widely grown than any other fruit with apple trees grown all around the world (Somogyi *et al.*, 1996). There are hundreds of apple cultivars, but only about 20 are commercially important (Bates *et al.*, 2001). More than 90 percent of production is represented by 14 cultivars with five cultivars accounting for most of the world's apple production.

Apples are most often eaten raw although the core is usually not eaten and can be discarded (presenting a possible opportunity for the transfer of some types of pests). Varieties bred for raw consumption are termed dessert or table apples. Apples can be milled or pressed to produce apple juice, which may be drunk unfiltered or filtered. Apple varieties used to produce cider are called cider apples. Apple juice can be fermented to make cider and vinegar. When distilled, apples can be used to produce alcoholic spirits such as Calvados. Many apple varieties have dual use as both dessert/tables apples and as apples for processing. Processed apples are an important ingredient in many desserts, such as apple pie, apple crumble and apple cakes. Cooking apples are often baked or stewed but can also be dried for later use. Apples can also be puréed to produce apple sauce.

The most important use of apples worldwide is their fresh consumption of the fruit although substantial quantities are processed into juice and other products (CABI CPC, 2013) e.g. dried fruit, fruit juice, canned fruit, frozen fruit and alcoholic beverages and also processed as ingredients for other foods. Fermentation of fruit of certain cultivars yields cider and distillation gives high-proof alcohol products. The use of whole or sliced cooked fruit in pastries is also common (CABI CPC, 2013).

Although some cultivars e.g. Bramley, are grown exclusively for use in processing, a proportion of all commercial apple cultivars are used in processed products. Bates *et al.* (2001) estimated around 20% of dessert apples are used for processing. Only sound, ripe fruit should be used for further processing because decay and damage such as that caused by pests and diseases, impact the quality of the product (Bates *et al.*, 2001). Most of the apples that are sold for processing are salvaged fruit grown for the fresh (dessert/table) market.

B.20 Fresh fruit for consumption

The EU is one of the leading producers and consumers of apples in the world. Poland, Italy and France are the largest EU producers, growing 23%, 21% and 17% of EU apple production respectively (Krautgartner *et al.*, 2013). Apples are the most popular fruit in all Member States except for Spain, where oranges are number one. However, there are differences in consumer preferences between Member States.

In Europe there is a lack of statistical data concerning fresh fruit distribution channels (Lemanowicz & Krukowski, 2009). Nevertheless, fresh fruit consumed by the public could be assumed to be distributed within the EU according to population density (based on import data, trans-shipments and NUTS 2 population density). However, we recognize that this is an over simplification, as average consumption of fresh fruit (and vegetables) varies within Europe with higher intakes in southern MS compared to northern MS. Fruit and vegetable consumption patterns are determined by a wide range of factors:

- Age, gender and socio-economic status – but also influenced by food preferences, knowledge, skills and affordability,
- Personal factors such as self-esteem, perceived time constraints, personal values and perception of the healthiness of one's own diet,

Social environment - social support, social cues and meal patterns and atmosphere at meal time etc. influence food preferences and attitudes towards fruit and vegetables, thus determining our food choices and dietary behaviours (EUFIC, 2012)

In relation to consumption of apples Konopacka *et al*. (2010), conducted surveys in seven European countries and asked participants to report how many apples they consumed each week. Fruit intake showed significant differences between nationalities. The highest apple consumption was in Poland, while the lowest was in the Netherlands and Spain (Table B.20.01).

Table B.20.01: Self-reported consumption of apples in seven European countries, differences between nationalities (%) (Source: Konopacka *et al*., 2010)

	Consumption habit (apples per week)			
Country	**0**	**1–2**	**3–5**	**>5**
Poland (*n* = 440)	2.3 (−)*	15.5 (−)*	26.8 (−)*	55.5 (+)*
Italy (*n* = 875)	4.5 (−)*	23.7 (−)*	39.3 (+)*	32.6
France (*n* = 651)	6.0	33.3	29.6 (−)*	31.0
Mean Total (*n* = 4271)	***5.6***	***29.8***	***33.6***	***31.0***
Switzerland (*n* = 550)	4.0 (−)*	32.7	33.6	29.6
Germany (*n* = 439)	5.5	32.6	34.9	27.1(−)*
Netherlands (*n* = 440)	9.1 (+)*	34.1 (+)*	32.7	24.1(−)*
Spain (*n* = 876)	7.4	35.3 (+)*	34.0	23.3 (−)*

Key = *Significantly different from average percentage distribution, (+) positive difference from the mean, (−) negative difference from the mean.

With regard to the case study of apples from North America, there is no evidence of trans-shipment of North American apple imports and we assume that the volume of apples entering each EU MS will be in accordance with consumer demand. Thus we assume that apples arriving into any EU MS from either Canada or USA are distributed in proportion to population density at NUTS2 regional level.

Contribution to model input parameters
An estimate of the likelihood of infested fruit being discarded following partial consumption by a consumer - see Table 3.1.03 of main report.

B.21 Apples used in processing

There is no data available that identifies the quantities of apples imported from Third Countries that are destined for processing (i.e. there is no CN code with such a commodity description, see Appendix 2). In a supply chain analysis (Anon, 2013) which included a report describing marketing of apples from Turkey, it was noted that all (i.e. 100%) of the fresh apples exported from Turkey were destined for consumer consumption as dessert apples. Given the cost of transport and storage, it is anticipated that the vast majority of apples from Third Countries are imported for consumption as fresh fruit. Nevertheless, although we have no evidence that fresh apples imported from North America have in the past been specifically imported for processing, it can be assumed that if the market price falls for fresh apples (dessert apples / table apples), such that the cost of maintaining imported apples in cold storage or in controlled atmospheres becomes unacceptable, then such apples will be shifted into processing.

The amount of apples diverted from fresh consumption to apple juice, baking or other processing stream depends on the prices available for dessert and processing apples. When the price for selling apples for processing goes up, a higher proportion of apple fruit will enter the processing stream, mainly going into juice production (Krautgartner *et al*., 2013).

For the purposes of estimating the quantity of apples from North America being used in processing, a number of assumptions need to be made: (i) all fresh apples from North America enter the EU with the intention that they are sold for fresh consumption (i.e. not initially intended for processing); (ii) nevertheless, a proportion of imported apples go to processing according to market conditions; (iii) the origins of apples used in processing will be proportion to the volumes of apples domestically produced and imported.

The majority of apple supply within the EU is provided by domestic production and internal trade, with between 5% and 8% of the total EU apple supply being provided from outside the EU. However, more recent data suggests that between 4.0 and 4.7% of apple supply within the EU is provided by Third countries (Table B.21.01; from Krautgartner *et al*., 2013).The USA provide around 2% of total EU apple imports (Krautgartner *et al*., 2013) whilst North America (USA + Canada) provide an estimated 3% (2.5% - 2.73%) of EU apple imports (Table B.21.01). Hence apples from USA and Canada represent an estimated 0.11% to 0.12% of total EU apple supply (Table B.21.01). The amount of apples imported from USA and Canada has been falling in recent years, and this trend is expected to continue.

Bates *et al*. (2001) estimated around 20% of dessert apples are used for processing. More recently Krautgartner *et al*. (2013) estimated 24.5% to 27.3% of total EU apple supply was used for processing. Based on such information, it is reasonable to assume that a maximum of between 20% and 27% of imported North American apples are used for processing.

Table B.21.01: EU Apple supply and uses for marketing years 2011/12 to 2013/14 (Source: Krautgartner *et al.*, 2013)

Marketing year (Aug – July)	2011/12		2012/13		2013/14	
Supply	tonnes	%	tonnes	%	tonnes	%
Commercial production	10,790,549	83.9	9,956,435	82.9	10,217,308	85.0
Non-commercial production	1,547,039	12.0	1,483,435	12.4	1,242,485	10.3
Total production	12,337,588	96.0	11,439,870	95.3	11,459,793	95.3
Imports (all TCs)	517,834	4.0	564,709	4.7	555,000	4.6
Total Supply	12,855,422	100.0	12,004,579	100.0	12,014,793	100.0
Imports from USA	10,808		10,733		?	
from Canada (estimated)	3,332		3,407		?	
Total from USA or Can (est.) [a]	14,140		14,140		14,140	
% imports from N Am		2.73		2.50		2.55
% total supply from N Am		0.11		0.12		0.12
Uses						
Fresh domestic consumption	8,068,800	62.9	7,159,280	59.6	7,549,321	62.8
For Processing [b]	3,280,622	25.5	3,273,010	27.3	2,948,472	24.5
For Export	1,506,000	11.7	1,572,289	13.1	1,517,000	12.6
Total Distribution	12,855,422	100.0	12,004,579		12,014,793	100.0
N Am apples for processing (Estimate as [a] x [b]) (tonnes)	3,608		3,855		3,470	

As noted above, apples are processed into a variety of products, with apple juice being by far the largest sector within processed apple products. Apple juice is processed from apples that are unsuitable for peeling, (apples < 57mm diameter which are regarded as too small to peel). There are several forms of apple juice, for example:

- fresh apple juice (bottled or packaged with no form of preservation although it is pasteurized to eliminate *E. coli* or other human pathogens),
- cider (fermented apple juice),
- shelf-stable apple juice (juice that has been treated for preservation), including clarified juice (depectinized, filtered, pasteurized and bottled),
- crushed apple juice (pasteurized and with a high pulp content),
- natural unfiltered juice or juice concentrate,
- frozen (natural or clarified and concentrated).

Other liquid apple products include apple squash and soft drinks that contain a very small amount of fruit juice. Only sound, ripe fruit should be used for further processing because decay and damage such as that caused by pests and diseases, impact the quality of the product (Bates *et al.*, 2001). Most of the apples that are sold for processing are salvaged fruit grown for the fresh (dessert / table) market.

The share of apples used for processing varies significantly by Member State, ranging from 2% in France to well over 60% in Hungary. The processing share also varies from year to year. Major Member States with apple processing, in order of descending volume, include Poland, Germany, Hungary, Italy, Romania, France, Austria, Spain, and the UK (Krautgartner *et al.*, 2013).

No EU data could be found describing the utilization of apples for processing in Europe. However, the US Apple Association produced a market analysis of US production in 2011 and reported 67.7% of apples were consumed fresh, 14.4% used for juicing, 11.2% canned, 1.9% frozen, 1.8% dried, 1.4% fresh sliced and 0.8% were not marketed (USApple, 2011)[15]. Considering only the apples used in processing, 46.9% were for juice, 36.5% were canned, 6.2% were frozen, 5.9% were dried and 4.6% were sliced. The proportion of apple processed in each category varies year to year (USApple, 2011; Krautgartner *et al.*, 2013) although juicing is always the largest use for processed apples. It is recognised that US and European consumers behave differently and it is assumed a smaller proportion of apples in Europe will be canned. Nevertheless, without alternative data, we will assume almost 50% of apples processed in Europe are used in juicing.

B.22 Location of fruit processors

Within the EU, business activities are classified according to the Nomenclature of Economic Activities code (in French, named *Nomenclature statistique des activités économiques dans la Communauté européenne* – leading to the codes commonly being referred to as NACE codes). The EU NACE codes align with the UN International Standard Industrial Classification (ISIC) system. Like CN import codes, NACE and ISIC codes have a hierarchical, top-down structure that begins with general characteristics and narrows down to the specifics. The first two digits of the code represent the major industry sector to which a business belongs. The third and fourth digits describe the sub-classification of the business group and specialization, respectively. Statistics produced on the basis of NACE are comparable at European level and, in general, at world level (Eurostat European Commission, 2008).

The codes used to describe business activities are listed in the most recent version of the NACE codes in Eurostat European Commission (2008). Codes used to identify businesses involved in the processing and preserving of fruit and vegetables are listed in Table 14. The EC produced a report on various NACE Groups, including the processing and preserving of fruit and vegetables[16]. In summary, in 2006 there were approximately ten thousand business enterprises across the EU (27) whose main activity was the processing and preserving of fruit and vegetables, employing over 280,000 people. The production index for processed and preserved fruit and vegetables grew relatively strongly between 2000 and 2007 (averaging 3.4 % per year). Growth in Poland was particularly strong (10.8 % per year).

Whilst the Eurostat Structural business statistics (SBS) database[17] contains business information to the NACE group level (i.e. 3 digits) at the scale of each EU Member State, it holds information at NUTS2 spatial resolution at the division level (i.e. 2 digits).

Table B.22.01: NACE codes used to identify businesses involved in the processing and preserving of fruit and vegetables.

Class	Division	Group	Class	Description
C				Manufacturing
	10			Manufacture of food products
		10.3		Processing and preserving of fruit and vegetables
			10.31	Processing and preserving of potatoes
			10.32	Manufacture of fruit and vegetable juice
			10.39	Other processing and preserving of fruit and vegetables

[15] Apple utilization % do not sum to 100% due to rounding errors.

[16] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Archive:Fruit,_vegetable,_oil_and_grain_processing_statistics_-_NACE_Rev._1.1#Processing_and_preserving_of_fruit_and_vegetables_.28NACE_Group_15.3.29

[17] http://epp.eurostat.ec.europa.eu/portal/page/portal/european_business/data/database

Table B.22.02 lists the number of business enterprises processing fruit and/or vegetables (NACE code 10.3) by EU MS. Note that not all of the processing units in Table 15 will be involved in the processing of apples. For example, many in southern Europe will focus on citrus fruit whilst others elsewhere in Europe will specialise in vegetables such as potatoes.

Table B.22.02: Number of business enterprises processing and preserving fruit and/or vegetables by EU MS. (Source: Eurostat SBS[8])

EU Member State	Processors in 2012			
Italy	1,738		Belgium	163
Spain	1,331		Netherlands	153
France	1,235		Slovakia	141
Poland	1,050		Finland	156
Germany	648		Croatia	138
Greece	594		Czech Republic	145
United Kingdom	526		Austria	125
Hungary	533		Latvia	57
Bulgaria	339		Estonia	44
Lithuania	326		Cyprus	41
Slovenia	149		Ireland	31
Portugal	269		Denmark	62
Romania	266		Luxembourg	3
Sweden	249		Malta	-

To estimate the distribution of fruit and vegetable processors within each EU Member State at NUTS 2 level (to fit the quantitative pathway model), the number of fruit and vegetable processors in each EU MS have been allocated to NUTS2 in proportion to business activity at NACE Division level (NACE code 10). Figure B.22.01 shows the distribution of fruit and vegetable processing sites at the NUTS2 scale (no data were available for Ireland or Malta). Appendix 4 provides that actual number of estimated processors for each NUTS2 region.

B.23 European Association of Fruit and Vegetable Processors

The European Association of Fruit and Vegetable Processors (PROFEL) represents over 500 companies across Europe. They were approached for information regarding the geographic location of their members. The Secretary General of PROFEL replied that the direct members of PROFEL are the national associations of fruit & vegetable processors and that individual national associations should be approached for information regarding the location of members. Contact details per country are available on the PROFEL website: http://www.profel-europe.eu/profel-members/national-associations

All national bodies were approached. Germany and Belgium replied. A map of German members of PROFEL who process fruit is shown in Figure B.23.01[18] whilst sites that process both fruit and vegetables is shown in Figure B.23.02. Information about PROFEL processors indicated in the maps in Figs. B.23.01 and B.23.02 are presented in Tables B.23.01 and B.23.02.

[18] http://batchgeo.com/map/d9463fc8e869770d77c76e0af7ebb232

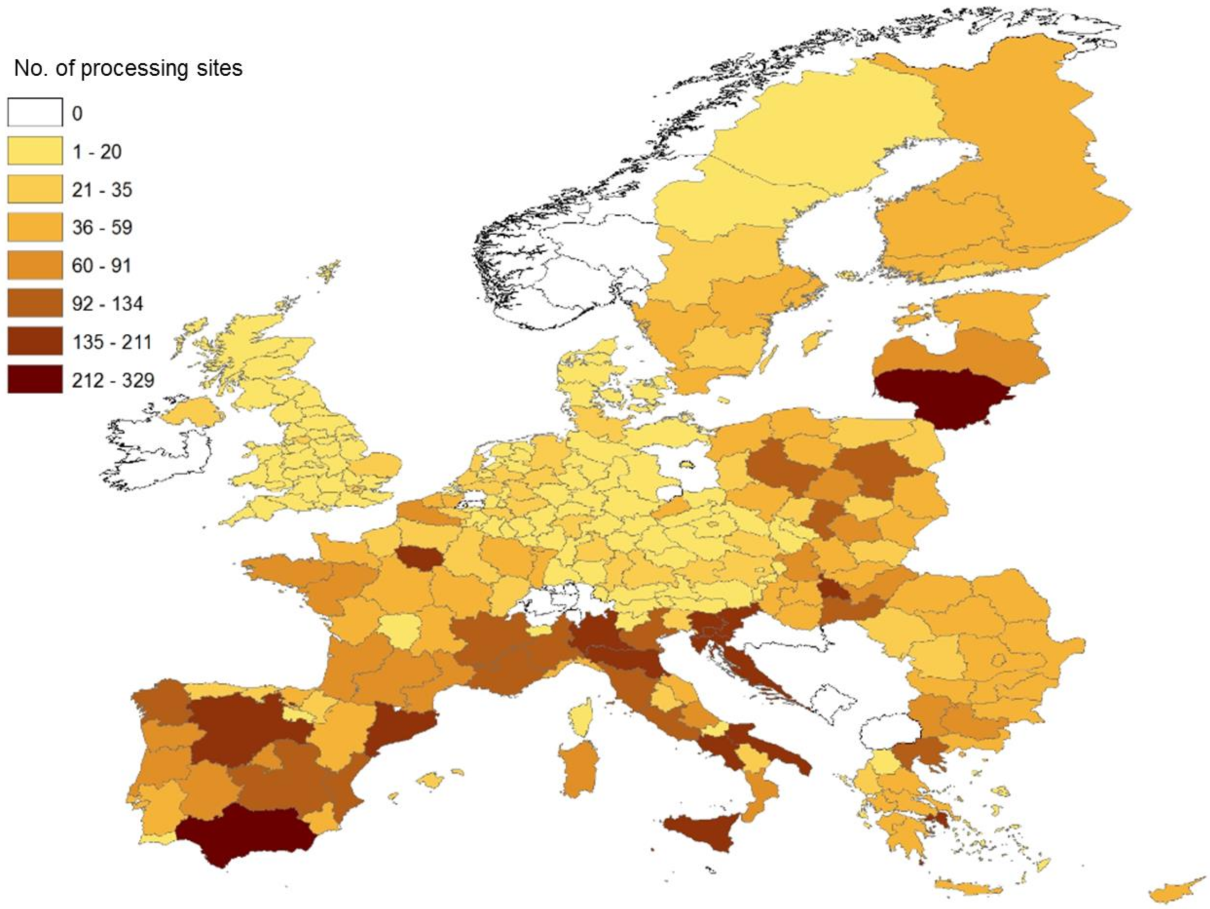
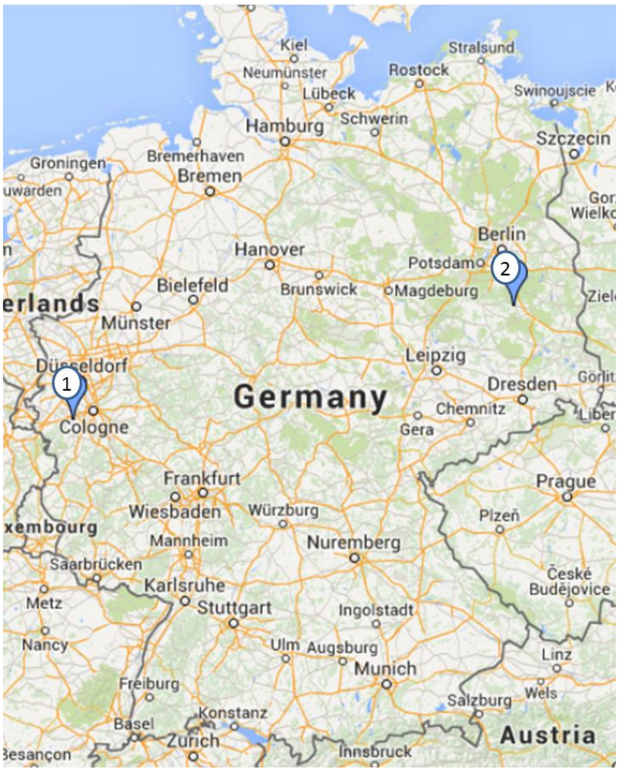


Figure B.22.01: Numbers of fruit and/or vegetable processing sites in the EU at NUTS2 (estimate)

Figure. B.23.01: Location of fruit processers in Germany	**Figure B.23.02:** Location of fruit and vegetable processers in Germany



The websites of German members of PROFEL were examined. Of those businesses that did mention the source of their fruit, none reported that apples (or plums) are imported for processing. Many highlighted the fact that the fruit that was processed was sourced locally. A few sites do refer to imports of exotic fruit (e.g. pineapples) and mention the country where they are sourced from.

No information was obtained regarding the volume of processing at each site each month.

Given that NACE data suggests there are 648 fruit and vegetable processors in Germany (Table B.22.02), PROFEL membership does not sufficiently capture the distribution of businesses potentially involved with processing apples and no more effort was spent trying to collect membership information from other PROFEL countries.

Table B.23.01: German members of PROFEL, Fruit processors

Ref	Company	Location	Products	website
1	FrüchteMeer,	Wankendorf, DE	Jams and jellies, sauces, syrups and preserved fruits	http://www.fruechtemeer-konfituerenmanufaktur.de/english/
2	Schwartauer Werke GmbH & Co. KG aA	Bad Schwartau, DE	Mainly jams	http://www.schwartauer-werke.de/
3	Göbber GmbH & Co. KG	Eystrup, DE	Jams, fruit syrups, fruit filling and fruit spreads	www.goebber.de/
4	Valenzi GmbH & Co. KG	Suderburg, DE	Forest fruit preserves, preserved mushrooms, soup ingredients, canned and frozen products	www.valenzi.de/

Ref	Company	Location	Products	website
5	Stute Nahrungsmittelwerke GmbH & Co. KG	Paderborn, DE	Fruit drinks, jams and canned fruit	http://www.stute-fruits.de/
6	Zentis GmbH & Co. KG *also sites in PL and HU*	Aachen, DE Żelków near Siedlce, PL Dregelpalank HU	Fruit preparations for the dairy, ice cream and bakery industries	http://www.zentis.de/cms/en/Company/About-us/Locations
7	Grafschafer Krautfabrik J. Schmitz KG *also sites in Hamburg (as HZR) and Beesel (NL) (as Frimarco)*	Meckenheim, DE Hamburg, DE Beesel, NL	Primarily sugar syrup from sugar beet, but also some jams and sauces (including using plum and apples). Collectively all 3 sites produce about 40,000t industrial syrups each year and 14,000t of jams and sauces.	http://www.grafschafter.de/web/datenschutz.html
8	Lausitzer Früchteverarbeitung GmbH	Sohland, DE	Juice, tinned food, jam, ingredients for delicatessen and desserts	http://www.lausitzer.de/en/
9	Odenwald-Früchte GmbH	Breuberg, DE	tinned fruit, jams, ingredients for desserts	http://www.odenwald-fruechte.de/
10	Mainfrucht GmbH & Co. KG Also site at Stainz, DE (as Gruenewald Fruchtsaft GmbH)	Gochsheim , DE Stainz, DE	Fruit juice concentrates, fruit purees, fruit preparations for the food industry (uses apples & plums)	http://www.gruenewald-international.com/Mainfrucht-GmbH-Co-KG.mainfrucht.0.html?&L=1 http://www.gruenewald-international.com/Gruenewald-Fruchtsaft-GmbH.gruenewald-fruchtsaft.0.html?&L=1
11	Maintal Konfitüren GmbH	Haßfurt / Main	jams and pie fillings	http://www.maintal-konfitueren.de/en/unternehmen/maintal-wir-ueber-uns/chronik/
12	Georg Baier GmbH	Pressath	canned mushrooms and berries (not plums or apples)	http://www.baier-online.com/en/index.html
13	Altvater-Spezialitäten	Bad Dürkheim	jams, jelly, alcoholic fruit drinks	
14	Wild Diary Ingredients GmbH	Eppelheim		http://www.wild-fruit.com/index.php?id=11&L=2
	Wild Diary Ingredients GmbH	Karas (Poland) site of fruit processing	cleaning, grading, freezing and packing of fresh fruit	http://www.wild-fruit.com/produktionsstaetten_karas.html?&L=2
15	Alfred Faller GmbH	Utzenfeld	jams	http://www.fallerkonfitueren.de/

Ref	Company	Location	Products	website
16	AGRANA Fruit Germany GmbH	Konstanz	supplies fruit preparations to dairy, ice cream, bakery and sweets industry	http://www.agrana.com/en
	AGRANA Fruit S.A.S. (France)			http://www.agrana.com/en/about-agrana/group-structure-corporate-profile/
	AUSTRIA JUICE GmbH (Austria)			http://www.agrana.com/en/about-agrana/group-structure-corporate-profile/
17	Adolf Darbo Ag	Stans/Tirol (Austria)	jams and preserved fruit	http://www.darbo.at/en#/en/history/history/

Table B.23.02: German members of PROFEL, Fruit and vegetable processors

Ref	Company	Location	Products	website
1	J.&W. Stollenwerk oHG	Kerpen	Local (Rhineland) sourced fruit and pickled salads and vegetables	http://www.stollenwerk-konserven.de/en/Unternehmen.html
2	Spreewaldkonserve Golßen GmbH	Golssen	Many vegetables and some fruit but focusses on cucumbers	http://www.spreewaldhof.net/

B.24 Processing activities

Table B.24.01 lists the types of products that apples and other case study commodities (described elsewhere) can be processed into. Note that all commodities can be used to produce all listed types of product. The majority of apples that undergo processing are processed to produce apple juice. Bates *et al.* (2001) provides a generalized flow diagram for the manufacture of apple juice.

Table B.24.01: Types of products that apple and other case study commodities can be processed to produce

Product type	Apples	Plums	Oranges
Fruit juices	✓	✓	✓
Fruit syrups	✓	✓	✓
Fruit - concentrates & pastes	✓	✓	✓
Fruit - canned / bottled	✓	✓	✓
Fruit - crystallised/ glace	✓	✓	✓
Fruit - dehydrated	✓	✓	✓
Fruit - dried	✓	✓	✓
Fruit - frozen	✓	✓	✓
Jams	✓	✓	✓
Preserves/ Conserves	✓	✓	✓
Fruit crush compounds	✓	✓	✓
Fruit - pulp	✓	✓	✓

Brandt & Martin (1994) provide more detailed flow diagrams for the processing of apples into apple juice, apple sauce and apple slices and includes points in the processing chains where "waste" is disposed of into other uses. All three processing systems lead either to waste being used for animal feed or being returned to land, e.g. as either land fill or as a soil improver. It is reasonable to assume that the processing of apples into products other than juice, sauce or slices also results in waste either being routed to animal feed or back to land.

B.25 Management of food processing residue

In order to meet stringent environmental requirements, modern fruit processing should minimize the amount of by-products and waste, to produce high-quality foodstuffs without polluting the soil, air or water (Barta *et al*., 1997; cited in Monspart-Senyi, 2006). Fruit processing waste is organic therefore decomposes and can be returned to soil. In addition, due to the relatively high water content it can be voluminous and often deteriorates quickly.

Fruit processing residues include residuals of fruit, unusable parts of fruits and fruits which do not meet size, quality, or other product specifications and which were intended for human or animal consumption (Michigan Department of Environmental Quality, 2007). Fruit residues can have value such as an animal feed source or as a fertilizer for crop production. The residue of apple processing is termed apple pomace and consists of apple peels, pulp and core. Recall that the case study pest burrows through the peel but does not reach the apple core. In 1950, Smock & Neubert (1950) (cited by National Research Council (1983)) estimated between 250kg and 350kg wet pomace are formed from each tonne of apples pressed for juice i.e. 25% - 35% of the quantity of apples used in juicing remains as pomace. UK produced 15,000 tonnes of wet apple pomace in 1987 (Table 1 in Kennedy *et al.,* 1999). Surprisingly, over 60 years later, modern processing techniques still operate at similar efficiencies. For example, De Paepe *et al.* (2015) reported 62.8% ± 1.5% efficiency with a "belt press" system and 77.7% ± 1.2% with a "spiral-filter press" system. Both such systems are suited to small and medium size enterprises. Larger scale juicing conventionally involves enzymatic maceration or thermal disintegration prior to pressing. Using a pulsed electric field (PEF) with a belt-press system, Turka *et al.* (2012) increased juice yield by 4.1% whilst Jaeger *et al.*, (2012) reported increased efficiency using PEF of up to 11%. Despite such improvements to belt-press systems, a recent review by Shalini & Gupta (2010) still suggests that juicing produces around **25%** waste. Of this waste, 20% is retrieved as animal feed and the rest (80%) is used for composting, landfill or incinerated (Dhillon *et al.,* 2012).

B.26 Animal feed (20%)

Fruit crops are not normally grown for animal feed, although certain by-products of the fruit processing industry are fed to animals. For example, the remaining tissue resulting from pressing apples (skins, stalk, pips/seeds and pulp) is either dried or sold moist, usually locally. Most apple pressing takes place during winter. Waste from apple juicing provides a good source of digestible fibre as animal feed but is low in protein. It is highly palatable and ideal for most ruminants as a replacement for forage but needs mineral supplements as it is naturally low in minerals. Apple pulp can store for 6 months (Ewing, 1997). As illustrated and highlighted in Figures B.24.02-04 apple residue from at least three apple processing systems can be used for animal feed. It is reasonable to assume that the residue from all other apple processing systems can also contribute to animal feed. Apple processors can improve the quality, and hence value, of apple residues destined for animal feed by applying any of the five methods listed in Table B.26.01 (Harpster *et al.*, 1993; Brandt & Martin, 1994). Ensiling is particularly favoured as it provides a means of storage which is often a major problem when managing food residues. Additionally, ensiling provides an opportunity for blending with other feed materials to improve the formulation (as apple residues are low in protein) and form a more complete feed mixture. As ensiling involves storage of feed material in an anaerobic environment to encourage fermentation, it will also make survival of any insects contaminating the mixture less likely. The last column in Table B.26.01 provides a comment regarding the likelihood of any insect pests, such as eggs or larvae of *Cydia prunivora* (the case study pest) surviving the treatment method.

More recently, Monspart-Senyi (2006) reported pomace being dried and formed into pellets for animal feed. The moisture content and feed value of such products are continuously checked to ensure they are of consistent quality (Bennett, 2002).

Table B.26.01: Treatment methods to improve the animal feed value of food processing "waste" (based on Harpster *et al*., 1993)

Method	Detail	Likely to cause mortality to insects in waste?
Mechanical	Grind, chop, pelletixe, extrude, screen, roll	Yes. Very likely. Larvae are 7.5 – 9.5mm (Smith *et al*., 1997a) hence are sufficiently large to be physically and mortally damaged if they enter mechanical treatments.
Heat	Dry heat, roast, micronize, pop, flash dry, dehydrate	Yes. Very likely, temperatures will exceed survivable limits
Chemical	Treat with acid, alkali, or ammonia	Yes. Very likely, pH likely to exceed survivable limits.
Biological	Bacterial cultures, anaerobically digest, compost	Anaerobic digestion – Yes. The anoxic environment will destroy larvae. Composting - some chance of survival if not managed properly (see text below).
Ensiling	Vertical (conventional, air-tight), horizontal (trench, bunker, pit, pile, large bag), round bale (bagged, wrapped)	Yes – anaerobic conditions will destroy larvae.

Composting: A well-managed composting system will achieve temperatures of 60-65°C for several days and will be effective at eliminating insect pests from infested fruit (review by Sansford & MacLeod, 1998). However, less well managed systems that do not efficiently turn and combine the components of the compost pile can allow insect pests to survive at the margins of the compost where temperatures do not reach lethal limits (Bishop *et al*. 2002; Keen *et al*., 2002).

Contribution to model input parameters

An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via animal feed according to method of treatment (based on Table A2.26.01)

Mechanical = 0% survival

Heat = 0% survival

Chemical = 0% survival

Biological = ? % survival in poorly managed composting systems. (Guess 20%)

Ensiling = 0% survival

B.27 Land application (80%)

"Land application" is a term to describe the destination of by-products or "waste" from food processing. After treatment, residue is either disposed of in landfills (which would incur costs) or applied to land where its fertilising properties can be used. Specifically with regard to apples, processing residues can be mixed with sawdust, leaves, soil or compost before being applied onto land using conventional farm machinery (Anon., 2001). In a review by Dhillon *et al*. (2012) 80% of pomace was disposed of via composting or landfill.

Contribution to model input parameters
An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via land application (based on Table 18)
Landfill = a small fraction will survive. If near the surface of the landfill, birds will feed on waste fruit / pomace, rotting fruit will degrade inhibiting larval development. If buried within landfill, emerging adults will not escape.
Composting = as in previous estimate, survival in poorly managed composting system = Guess 20%)

Contribution to model input parameters
Of the volume of apples going to processing, the majority of which is for apple juice, a mass of 25% is produced as waste.
% larval survival during processing = ? No data available
Assuming that some larvae can survive, we need an estimate of the volume processed further.
Adopt figures in Dhillon et al. (2012) (for Canada?) thus
20% of waste goes to animal feed
80% goes to land application (composting or land fill)
Any pests in pomace waste that is incinerated will be killed.

B.28 Secondary uses for apple pomace

An ideal use for apple pomace is yet to be found and researchers have been studying its potential since at least 1902 (Kennedy *et al.,* 1999). The use of apple pomace can be divided into two broad categories, (a) as a waste reduction strategy such as being used as animal feed or for composting (see above), or (b) further processed to extract high value products such as pectin, flavourings or compounds used in aromas (Table B.28.01).

High value plant phenolics can be extracted from macerated apple fruits, particularly from apple peels and apple cores, by agitating the macerated fruit material with hot water of sufficiently high temperature to deactivate naturally present polyphenol oxidase enzyme. The aqueous extract of plant phenolics is separated from the bulk of solid fruit material by physical means, such as filtration. The aqueous extract is treated with pectinase enzyme to remove pectin, then the pectinase enzyme is deactivated by heat. The plant phenolics are adsorbed from the depectinized aqueous extract by treatment with solid polyvinylpolypyrrolidone (PVPP) adsorbent, and the plant phenolics are eluted from the adsorbent by treatment with a nutritionally acceptable base, such as sodium hydroxide. The resulting aqueous solution of plant phenolics is concentrated or spray-dried and the resulting concentrated liquid or solid products are used as food supplements, and as additives to beverages and other food items, to provide the beverage or food item with a quantity of plant phenolics which is at least comparable to and which may exceed the plant phenolic contents of natural apple juice.

Table B.28.01: Secondary uses for apple pomace (Kennedy *et al*., 1999)

High value	Low value
Modification and incorporation into human food stuffs	Animal feed

Wine Pectin Ethanol production via fermentation Citric acid production via fermentation Butanol production via fermentation High protein feedstock via fermentation Extraction of enzymes Appel seed oil Apple vinegar Apple wax Aroma compounds / flavourings Oxalic acid Xyloglucan extraction Insect bait Activated carbon Ion exchange resin Furfural	Compost / fertilizer Fuel use Methane / biogas from waste treatment

Contribution to model input parameters

The processing (e.g. heat, chemicals) will destroy any pest contaminants in apple pomace being used in secondary processing.

% larval survival during processing = Nil

B.29 Dispersal of adults

To complete the modelling, an estimate of the potential dispersal of adults is required, in order to determine the likelihood of them encountering host plants on which to feed, mate and lay eggs from which an outbreak could emerge. However, providing a quantitative estimate regarding the likelihood of pest establishment is not a requirement of this model. Studying another tortricid pest of apples, (*C. pomonella*) Tyson *et al.* (2007) summarised existing literature, for example noting that flight mill experiments showed that adults are short-distance dispersers (Schumacher *et al.,* 1997). In mark-recapture studies, Thistlewood *et al.,* (2004) reported most adults were captured within 800m of release locations and none more than 3km away. However, one study observed a male dispersing up to 8km (Mani & Wildbolz, 1977). Females are less active, perhaps flying only a few hundred metres.

Adult dispersal

Model input: Minimum 0m Most likely: less than 800m Maximum: up to 3 (or 8km?)

B.29 Apple phenology in Europe

As well as considering dispersal ability, the availability of apple hosts must also be taken into account. Following mating, eggs are laid singly on the upper surface of host leaves and on young fruit. Hence the timing of when young fruit are available across Europe is taken into account in the model.

The timing of flowering and subsequent fruit development of apples varies largely according to latitude and cultivated variety. Examining temperature data and flowering date of full bloom between 1980 and 2011 for the apple variety "Golden Delicious" at a range of locations from southern to northern-central Europe Legave *et al*. (2013) reported that apples blossomed on average 22 days earlier in southern Europe (Nimes, France; Forli, Italy) than in central-northern Europe (e.g. Gembloux, Belgium & Bonn, Germany). Typically in southern Europe full bloom, the time at which around 50% of flowers are open, and which corresponds to growth stage 65 in the international BBCH code (Meier, 2001) occurs around mid-April (Julian day 105, April 15th) whilst in northern-central Europe full bloom occurs towards the end of the in first week of May (Julian day 127, May 7th).

In northern Europe (Lithuania), Romanovskaja & Bakšiene (2009) reported apple flowering to begin around May 16th (Julian day 136). Full flowering could be expected to occur towards the end of May, estimate Julian day 150.

Studying 15 cultivars at a single European location in northern Italy, Valentini *et al* (2001) reported a three week variation amongst the date of full flowering between cultivars, ranging from April 7th to April 22nd. Hence there can be as must variation between cultivars within a region as between regions in Europe.

Apple fruits grow by cell division and cell expansion. Most cell division occurs in the first 3 to 4 weeks following the end of flowering and fruit set, in late spring / early summer and by 7 weeks cell division has almost finished (HDC, 2002). Fruits remain on the tree ripening until harvest. In the northern hemisphere, apples are typically harvested in late summer and early autumn, September and October being the busiest harvesting months although harvests between early July and into November are possible, depending on climate and apple variety (Childers *et al.,* 1995).

As with other plants and crops, climate change appears to be having an effect in bringing forward key stages of phenology and development within apples (Romanovskaja & Bakšiene, 2009; Chmielewski *et al*., 2013).

Assuming that it is possible for adults to emerge from the pathways examined and have to fly to reach apple trees, we finally consider when threshold temperatures for flight coincide with availability of apple hosts. Using flight-tunnel assays and studying the related species *Cydia pomonella*, Judd & Gardiner (2006) reported the threshold temperature for flight of laboratory mass-reared adults to be 14.7ºC whilst the threshold for wild adults was 15.4ºC. Based on Judd & Gardener (2006), we assume that the threshold temperature for adult flight of *C. prunivora* is 15ºC. A figre at the end of this Appendix shows the weeks of the year when mean temperatures would be expected to exceed 15^{o}C (threshold for adult flight) using a cross (x) and divides Europe up into three regions (north, central and south). Approximate dates for apple flowering, fruit development and harvesting are indicated using a colour code. Where crosses (x) overlap colours, there is some likelihood that adult *Cydia prunivora* could fly and contact an apple host if it were within dispersal range (see B.29).

B.30 Inspection frequency

Table B.30.01: Dossier to support reduced inspection frequency of apples from USA (prepared 2004)

Description			
Reference	Malus/ US/ NL[1,2,3] + UK[1,2,3] + ES[1,2] + FR[1,2] + BE[1] (Genus/origin code/EUMS [year])		
Genus	*Malus*	**TARIC code**	08 08 10
Common name	Apples		
Origin country	Unites States of America	**Country code**	US

Import Record					
Importing MS	BE, DE, ES, FI, FR, GR, IR, IT, LU, NL, PT, SE, UK.				
Import record for NL[1,2,3] + UK[1,2,3] + ES[1,2] + FR[1,2] + BE[1]					
Imports	**Year**	**2001**	**2002**	**2003**	> 200 consig. /yr
	Tonnes (t)	31,541	25,808	25,278	
	consignments	1,060	1,010	937	**Yes**
	Total EU (t)	33,957	28,788	28,181	
	EU consignments (estimated)	1,141	1,127	1,045	1,104 Av
	UK[1,2,3] + NL[1,2,3] + ES[1,2] + FR[1,2] + BE[1] tonnes as % of total EU imports	92.9%	89.6%	89.7%	
Pest Risk					
Pest risks	EC quarantine pests liable to be carried by fruits of *Malus domestica* from the US: *Anastrepha fraterculus, Anastrepha ludens, Anastrepha suspensa, Anthonomus quadrigibbus, Bactrocera dorsalis, Conotrachelus nenuphar, Cydia packardi, Cydia prunivora, Monilinia fructicola, Rhagoletis pomonella*. (EPPO PQR v 4.3)				
	Pest name		**Mobility**	**Comments**	
	Anastrepha fraterculus, A. ludens, A. suspensa, Bactrocera dorsalis, Rhagoletis pomonella		High	Fruit flies: assume adults are soon to emerge	
	Anthonomus quadrigibbus Conotrachelus nenuphar		Medium	Weevils: assume adults are soon to emerge	
	Cydia packardi, Cydia prunivora		High	Lepidoptera: assume adults will emerge soon	
	Monilinia fructicola		Low	Fungi	
Risk Management Record for NL[1,2,3] + UK[1,2,3] + ES[1,2] + FR[1,2] + BE[1]					
Inspections	**Year**	**2001**	**2002**	**2003**	**3 year sum (>300)**
	Number of inspections	85	94	131	310
Notifications of non-compliance	**Year**	**2001**	**2002**	**2003**	**Total**
a) due to listed QPs	Number of interceptions	0	0	0	0
	QP Pest mobility				
	High	0	0	0	0
	Medium	0	0	0	0
	Low	0	0	0	0
b) for other reasons	**e.g. Document infringements & non listed harmful organisms**	0	0	0	0
Conclusion					
	No notifications of non-compliance were made to the EC by either NL[1,2,3], UK[1,2,3], ES[1,2], FR[1,2] nor BE[1] following 310 inspections during the period Jan. 2001 to Dec 2003. No other MS made any notifications to the EC during this period either.				

B.31 CN codes

Table B.31.01: Combined nomenclature (CN) codes within which apples are classified

08	CHAPTER 8 - EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MELONS
0808	Apples, pears and quinces, fresh
0808 10	Apples
0808 1010	Fresh cider apples, in bulk, from 16 September to 15 December
0808 1020	Fresh apples of the variety Golden Delicious
0808 1031	Apples of the variety Golden Delicious, fresh, from 1 August to 31 December
0808 1033	Apples of the variety Granny Smith, fresh, from 1 August to 31 December
0808 1039	Apples, fresh, from 1 August to 31 December (excl. cider apples, in bulk, from 16 September to 15 December, and applies of the varieties Golden Delicious and Granny Smith)
0808 1050	Fresh apples of the variety Granny Smith
0808 1051	Apples of the variety Golden Delicious, fresh, from 1 January to 31 March
0808 1053	Apples of the variety Granny Smith, fresh, from 1 January to 31 March
0808 1059	Apples, fresh, from 1 January to 31 March (excl. Apples of the varieties Golden Delicious and Granny Smith)
0808 1061	Fresh apples of the variety Golden Delicious, from 1 April to 30 June
0808 1063	Fresh apples of the variety Granny Smith, from 1 April to 30 June
0808 1069	Fresh apples, from 1 April to 30 June (excl. the varieties Golden Delicious and Granny Smith)
0808 1071	Fresh apples of the variety Golden Delicious, from 1 to 31 July
0808 1073	Fresh apples of the variety Granny Smith, from 1 to 31 July
0808 1079	Fresh apples, from 1 to 31 July (excl. the varieties Golden Delicious and Granny Smith)
0808 1080	Fresh apples -- Other (excl. cider apples, in bulk, from 16 September to 15 December)
0808 1081	Apples of the variety Golden Delicious, fresh, from 1 April to 31 July
0808 1083	Apples of the variety Granny Smith, fresh, from 1 April to 31 July
0808 1089	Apples, fresh, from 1 April to 31 July (excl. apples of the varieties Golden Delicious and Granny Smith)
0808 1090	Fresh apples (excl. cider apples, in bulk, from 16 September to 15 December, and the varieties Golden Delicious and Granny Smith)
0808 1091	Fresh apples, from 1 August to 31 December (excl. cider apples, in bulk, from 16 September to 15 December)
0808 1092	Fresh apples of the variety Golden Delicious, from 1 August to 31 December
0808 1093	Fresh apples, from 1 January to 31 March
0808 1094	Fresh apples of the variety Granny Smith, from 1 August to 31 December
0808 1098	Fresh apples, from 1 August to 31 December (excl. cider apples, in bulk, from 16 September to 15 December, and the varieties Golden Delicious and Granny Smith)
0808 1099	Fresh apples, from 1 April to 31 July

B.32 PROFEL contacts

Country	Association	Fruit and/or Vegetable Groups	tel	e-mail & website
Austria	Fachverband der Nahrungs- und Genussmittelindustrie Österreichs	Fruit and Vegetable Groups	Tel. +43 1 712 21 21	fiaa@dielebensmittel.at http://portal.wko.at/wk/startseite_dst.wk?DstID=323
Belgium	Association Royale des Fabricants de Confitures, Sirops à tartiner, Compotes, Conserves et Préparations de Fruits	Fruit Groups	Tel. +32 2 743 87 37	confitures@agep.eu
Belgium	VEGEBE- Verbond van Groentenverwerkende Bedrijven en Industriegroenten Groothandelaars en Exporteurs	Vegetable Groups	Tel. +32 2 238 06 20	romain@fvphouse.be http://www.vegebe.be
Finland	Elintarviketeollisuusliitto ry - Finnish Juice and Preserves Industries' Association	Fruit and Vegetable Groups	Tel. +358 9 1488 7228	elisa.piesala@etl.fi http://www.etl.fi
France	FIAC - Fédération Française des Industries d'Aliments Conservés	Fruit and Vegetable Groups	Tel. +33 1 53 91 44 44	fiac@adepale.org http://www.adepale.org/
Germany	BOGK - Bundesverband der obst-, gemüse- und kartoffelverarbeitenden Industrie e.V.	Fruit and Vegetable Groups	Tel. +49 228 9 329111	freitag@bogk.org http://www.bogk.org
Greece	EKE - Association of Hellenic Agricultural Processors	Fruit Groups	Tel. +30 23320 43237	eke@delcof.gr http://www.delcof.gr/
Hungary	MHKSz - Association of Hungarian Deepfreezing and Canning Industry	Fruit and Vegetable Groups	Tel + 36 12 61 75 78	huto@mhksz.hu
Italy	AIIPA - Associazione Italiana Industrie Prodotti Alimentari	Fruit and Vegetable Groups	Tel. +39 2 65 41 84	aiipabo@mclink.it http://www.aiipa.it/
Italy	CONFCOOPERATIVE	Fruit and Vegetable Groups	Tel.+39 06 469 781	deleo.f@confcooperative.it http://www.confcooperative.it
Netherlands	VIGEF - Vereniging van de Nederlandse Groenten- en Fruitverwerkende Industrie	Fruit and Vegetable Groups	Tel. +31 070 336 5270	info@vigef.nl www.vigef.nl
Spain	ASEVEC - Asociacion Espanola De Fabricantes De Vegetales Congelados	Vegetable Groups	Tel: +34 91 3844009	asevec@infonegocio.com
Spain	FENAVAL - Federación Nacional de Asociaciones de Transformados Vegetales y Alimentos Procesados	Fruit and Vegetable Groups	Tel. +34 91 541 29 31	fnacv01@fnacv.es http://www.fnacv.es/

B.33 Fruit and vegetables processors

Estimated number of fruit & vegetable processing enterprises in NUTS 2 regions across the EU (see Text for detail)

NUTS 2 region	No. enterprises	Region	No. enterprises	Region	No. enterprises	Region	No. enterprises
AT11 - Burgenland (AT)	6	DED4 - Chemnitz	38	FR82 - Provence-Alpes-Côte d'Azur	120	PT15 - Algarve	14
AT12 - Niederösterreich	25	DED5 - Leipzig		FR83 - Corse	14	PT16 - Centro (PT)	87
AT13 - Wien	11	DEE0 - Sachsen-Anhalt	16	FR91 - Guadeloupe (FR)	21	PT17 - Lisboa	51
AT21 - Kärnten	8	DEF0 - Schleswig-Holstein	30	FR92 - Martinique (FR)	13	PT18 - Alentejo	39
AT22 - Steiermark	17	DEG0 - Thüringen	19	FR93 - Guyane (FR)	5	PT20 - Região Autónoma dos Açores (PT)	8
AT31 - Oberösterreich	27	DK01 - Hovedstaden	2	FR94 - Réunion (FR)	23	PT30 - Região Autónoma da Madeira (PT)	6
AT32 - Salzburg	9	DK02 - Sjælland	1	HR03 - Jadranska Hrvatska	151	RO11 - Nord-Vest	42
AT33 - Tirol	11	DK03 - Syddanmark	2	HU10 - Közép-Magyarország	140	RO12 - Centru	38
AT34 - Vorarlberg	7	DK04 - Midtjylland	2	HU21 - Közép-Dunántúl	42	RO21 - Nord-Est	37
BE10 - Région de Bruxelles-Capitale	16	DK05 - Nordjylland	2	HU22 - Nyugat-Dunántúl	50	RO22 - Sud-Est	37
BE21 - Prov. Antwerpen		EE00 - Eesti	46	HU23 - Dél-Dunántúl	48	RO31 - Sud - Muntenia	36
BE22 - Prov. Limburg (BE)	15	EL11 - Anatoliki Makedonia, Thraki	39	HU31 - Észak-Magyarország	49	RO32 - Bucuresti - Ilfov	37
BE23 - Prov. Oost-Vlaanderen	41	EL12 - Kentriki Makedonia	108	HU32 - Észak-Alföld	86	RO41 - Sud-Vest Oltenia	28
BE24 - Prov. Vlaams-Brabant		EL13 - Dytiki Makedonia	17	HU33 - Dél-Alföld	95	RO42 - Vest	28
BE25 - Prov. West-Vlaanderen	42	EL14 - Thessalia	50	ITC1 - Piemonte	126	SE11 - Stockholm	45
BE31 - Prov. Brabant Wallon	4	EL21 - Ipeiros	25	ITC2 - Valle d'Aosta/Vallée d'Aoste	4	SE12 - Östra Mellansverige	38
BE32 - Prov. Hainaut	22	EL22 - Ionia Nisia	15	ITC3 - Liguria	57	SE21 - Småland med öarna	29
BE33 - Prov. Liège	22	EL23 - Dytiki Ellada	45	ITC4 - Lombardia	191	SE22 - Sydsverige	49
BE34 - Prov. Luxembourg (BE)	5	EL24 - Sterea Ellada	38	ITF1 - Abruzzo	61	SE23 - Västsverige	59
BE35 - Prov. Namur	9	EL25 - Peloponnisos	52	ITF2 - Molise	18	SE31 - Norra Mellansverige	24
BG31 - Severozapaden	37	EL30 - Attiki	143	ITF3 - Campania	181	SE32 - Mellersta Norrland	19
BG32 - Severen tsentralen	41	EL41 - Voreio Aigaio	17	ITF4 - Puglia	148	SE33 - Övre Norrland	18

NUTS 2 region No. enterprises		Region No. enterprises		Region No. enterprises		Region No. enterprises	
BG33 - Severoiztochen	40	EL42 - Notio Aigaio	20	ITF5 - Basilicata	25	SI01 - Vzhodna Slovenija	157
BG34 - Yugoiztochen	52	EL43 - Kriti	49	ITF6 - Calabria	84	SI_X_021 - Slovenia except Osrednjeslovenska	139
BG41 - Yugozapaden	89	ES11 - Galicia	113	ITG1 - Sicilia	211	SK01 - Bratislavský kraj	12
BG42 - Yuzhen tsentralen	85	ES12 - Principado de Asturias	32	ITG2 - Sardegna	63	SK02 - Západné Slovensko	72
CY00 - Kypros	38	ES13 - Cantabria	21	ITH1 - Provincia Autonoma di Bolzano	9	SK03 - Stredné Slovensko	39
CZ01 - Praha	23	ES21 - País Vasco	53	ITH2 - Provincia Autonoma di Trento	9	SK04 - Východné Slovensko	35
CZ02 - Strední Cechy	15	ES22 - Comunidad Foral de Navarra	29	ITH3 - Veneto	107	UKC1 - Tees Valley and Durham	9
CZ03 - Jihozápad	15	ES23 - La Rioja	19	ITH4 - Friuli-Venezia Giulia	24	UKC2 - Northumberland and Tyne and Wear	9
CZ04 - Severozápad	10	ES24 - Aragón	50	ITH5 - Emilia-Romagna	157	UKD1 - Cumbria	8
CZ05 - Severovýchod	18	ES30 - Comunidad de Madrid	71	ITI1 - Toscana	98	UKD3 - Greater Manchester	22
CZ06 - Jihovýchod	25	ES41 - Castilla y León	141	ITI2 - Umbria	28	UKD4 - Lancashire	19
CZ07 - Strední Morava	16	ES42 - Castilla-la Mancha	110	ITI3 - Marche	55	UKD6 - Cheshire	8
CZ08 - Moravskoslezsko	16	ES43 - Extremadura	69	ITI4 - Lazio	108	UKD7 - Merseyside	8
DE11 - Stuttgart	34	ES51 - Cataluña	155	LT00 - Lietuva	329	UKE1 - East Yorks and Northern Lincolnshire	17
DE12 - Karlsruhe	20	ES52 - Comunidad Valenciana	103	LU00 - Luxembourg	3	UKE2 - North Yorkshire	14
DE13 - Freiburg	18	ES53 - Illes Balears	21	LV00 - Latvija	62	UKE3 - South Yorkshire	7
DE14 - Tübingen	18	ES61 - Andalucía	281	MT00 - Malta		UKE4 - West Yorkshire	19
DE21 - Oberbayern	35	ES62 - Región de Murcia	54	NL11 - Groningen	4	UKF1 - Derbyshire and Nottinghamshire	14
DE22 - Niederbayern	15	ES63 - Ciudad Autónoma de Ceuta (ES)	1	NL12 - Friesland (NL)	7	UKF2 - Leicestershire, Rutland and Northants	17
DE23 - Oberpfalz	11	ES64 - Ciudad Autónoma de Melilla (ES)	1	NL13 - Drenthe	4	UKF3 - Lincolnshire	10
DE24 - Oberfranken	10	ES70 - Canarias (ES)	45	NL21 - Overijssel	10	UKG1 - Herefordshire, Worcs & Warwicks	12
DE25 - Mittelfranken	12	FI19 - Länsi-Suomi	47	NL22 - Gelderland	22	UKG2 - Shropshire and Staffordshire	14
DE26 - Unterfranken	11	FI1B - Helsinki-Uusimaa	21	NL23 - Flevoland	4	UKG3 - West Midlands	15
DE27 - Schwaben	23	FI1C - Etelä-Suomi	39	NL31 - Utrecht	11	UKH1 - East Anglia	25
DE30 - Berlin	14	FI1D - Pohjois- ja Itä-Suomi	43	NL32 - Noord-Holland	26	UKH2 - Bedfordshire and Hertfordshire	10
DE40 - Brandenburg		FI20 - Åland	2	NL33 - Zuid-Holland	28	UKH3 - Essex	10

NUTS 2 region	No. enterprises	Region	No. enterprises	Region	No. enterprises	Region	No. enterprises
DE50 - Bremen	5	FR10 - Île de France	156	NL34 - Zeeland	4	UKI1 - Inner London	28
DE60 - Hamburg	10	FR21 - Champagne-Ardenne	27	NL41 - Noord-Brabant	27	UKI2 - Outer London	33
DE71 - Darmstadt	26	FR22 - Picardie	30	NL42 - Limburg (NL)	11	UKJ1 - Berks, Bucks and Oxfordshire	13
DE72 - Gießen	7	FR23 - Haute-Normandie	33	PL11 - Lódzkie	77	UKJ2 - Surrey, East and West Sussex	17
DE73 - Kassel	11	FR24 - Centre (FR)	50	PL12 - Mazowieckie	128	UKJ3 - Hampshire and Isle of Wight	10
DE80 - Mecklenburg-Vorpommern	19	FR25 - Basse-Normandie	36	PL21 - Malopolskie	82	UKJ4 - Kent	10
DE91 - Braunschweig	8	FR26 - Bourgogne	37	PL22 - Slaskie	114	UKK1 - Gloucestershire, Wilts and Bristol	16
DE92 - Hannover	15	FR30 - Nord - Pas-de-Calais	66	PL31 - Lubelskie	59	UKK2 - Dorset and Somerset	16
DE93 - Lüneburg	20	FR41 - Lorraine	45	PL32 - Podkarpackie	44	UKK3 - Cornwall and Isles of Scilly	10
DE94 - Weser-Ems	29	FR42 - Alsace	37	PL33 - Swietokrzyskie	28	UKK4 - Devon	14
DEA1 - Düsseldorf	31	FR43 - Franche-Comté	30	PL34 - Podlaskie	30	UKL1 - West Wales and The Valleys	19
DEA2 - Köln	24	FR51 - Pays de la Loire	74	PL41 - Wielkopolskie	108	UKL2 - East Wales	10
DEA3 - Münster	24	FR52 - Bretagne	86	PL42 - Zachodniopomorskie	38	UKM2 - Eastern Scotland	17
DEA4 - Detmold	18	FR53 - Poitou-Charentes	42	PL43 - Lubuskie	21	UKM3 - South Western Scotland	20
DEA5 - Arnsberg	16	FR61 - Aquitaine	79	PL51 - Dolnoslaskie	54	UKM5 - North Eastern Scotland	9
DEB1 - Koblenz	11	FR62 - Midi-Pyrénées	75	PL52 - Opolskie	25	UKM6 - Highlands and Islands	11
DEB2 - Trier	5	FR63 - Limousin	18	PL61 - Kujawsko-Pomorskie	45	UKN0 - Northern Ireland (UK)	32
DEB3 - Rheinhessen-Pfalz	17	FR71 - Rhône-Alpes	134	PL62 - Warminsko-Mazurskie	32		
DEC0 - Saarland	10	FR72 - Auvergne	37	PL63 - Pomorskie	43		
DED2 - Dresden	15	FR81 - Languedoc-Roussillon	65	PT11 - Norte	91		

B.33 Apple production and processing units

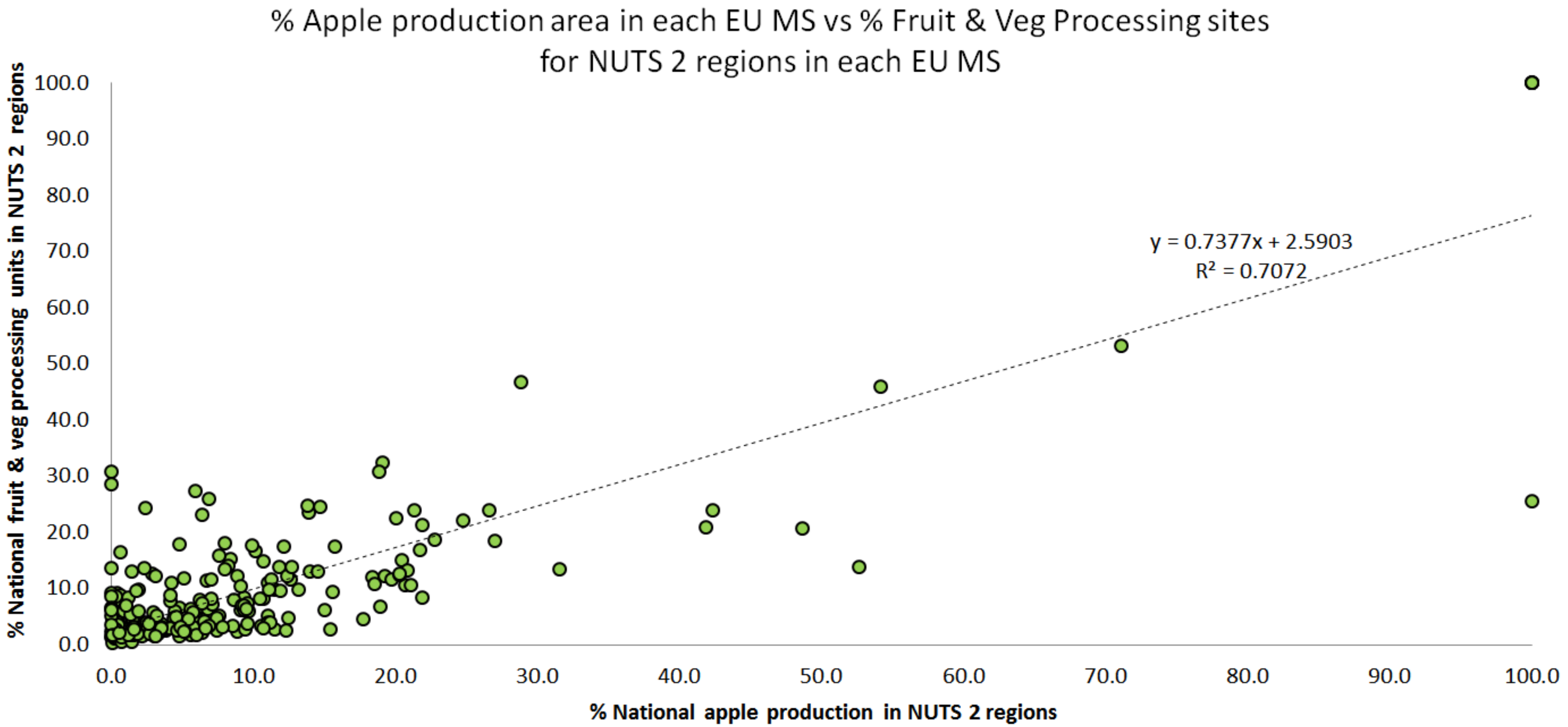


Figure B.33.01: Relationship between the percentage of national apple production area in EU countries NUTS2 regions (x-axis) and the percentage of each countries fruit and vegetable processing units in NUTS2 regions (y axis)

B.34 Apple phenology

Table B.34.01: Approximate dates of apple flowering (green), fruit development (sand) and harvesting (pink) across three regions of Europe (as shown using Julian days). The time when mean temperature exceeds 15°C (threshold for adult flight) is shown by crosses (x). Where crosses overlap colours, there is a likelihood that adult *Cydia prunivora* could contact an apple host.

Julian day	5	30	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340
Month	Jan	Feb	Mar						Apr						May						Jun						Jul						Aug							Sept						Oct						Nov						Dec	
North																					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x														
Central											x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
Southern				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

full flowering | fruit developing | fruit harvest

Threshold temp for flight assumed to be 15C
(Judd & Gardiner, 2006)

x = days with mean temp 15 C or more

Appendix C – Case study: Stone fruit (plums) from USA or Canada with potential infestation by *Conotrachelus nenuphar*

C.1 Introduction

The project had already selected the case study commodities and pests as shown in Table C.1.01.

Table C.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities and pests

Commodity	Pest	Common name	Case study countries
Pome fruit: Fresh apples	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit: Fresh plums	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus: Sweet oranges	*Xanthomonas citri citri*	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries).
Cereals: Wheat	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

To inform parameterization of the pathway model for *Conotrachelus nenuphar* on stone fruit (plums), this report collects information on aspects such as the distribution of the pest at pathway origin; pest life cycle; commodity production and practices; exports and pest survival; commodity uses, commodity processing and waste management, and location of processors.

The information is used to provide the rationale for selecting the estimated values for the quantitative inputs required in the quantitative models describing the likelihood of pest entry via the selected case study pathway. The report begins by examining the pathway origin and pest lifecycle.

C.2 Occurrence of case study pest at origin (Canada & USA)

Conotrachelus nenuphar (Herbst) (Coleoptera: Curculionidae) the plum weevil / plum curculio, is a native North American weevil and a pest of rosaceous plants. It is mainly found east of the Rocky Mountains between 28°N and 50°N (Smith *et al.*, 1997), i.e. from southern Texas and mid-Florida in the USA, north into the southern parts of Canadian provinces.

Figure C.2.01 indicates the Canadian provinces in which Bousquet (1991) lists *C. nenuphar* occurrence. Given that Smith *et al.* (1997) reports that the pest occurs mainly south of 50°N, the beetle is predominantly distributed only within a small proportion of Canada.

Commercial plum production occurs in the milder areas of British Colombia, Ontario and Nova Scotia, with the majority of production grown for the fresh domestic market (Table C.2.01). A small proportion of plums are exported (generally less than 1% per year) and do not appear in the top 15 of Canadian fresh fruit export commodities by value or volume (Agriculture and Agri-Food Canada, 2012). The USA and Japan are the largest export markets for Canadian fresh fruit.

Figure C.2.01: Canadian Provinces where *Conotrachelus nenuphar* occurs (Bousquet, 1991)

Table C.2.01: Canadian production statistics for plums (tonnes) (2006-2010) (Source: Agriculture and Agri-Food Canada (2011), Tables 41b, 42b, 43b)

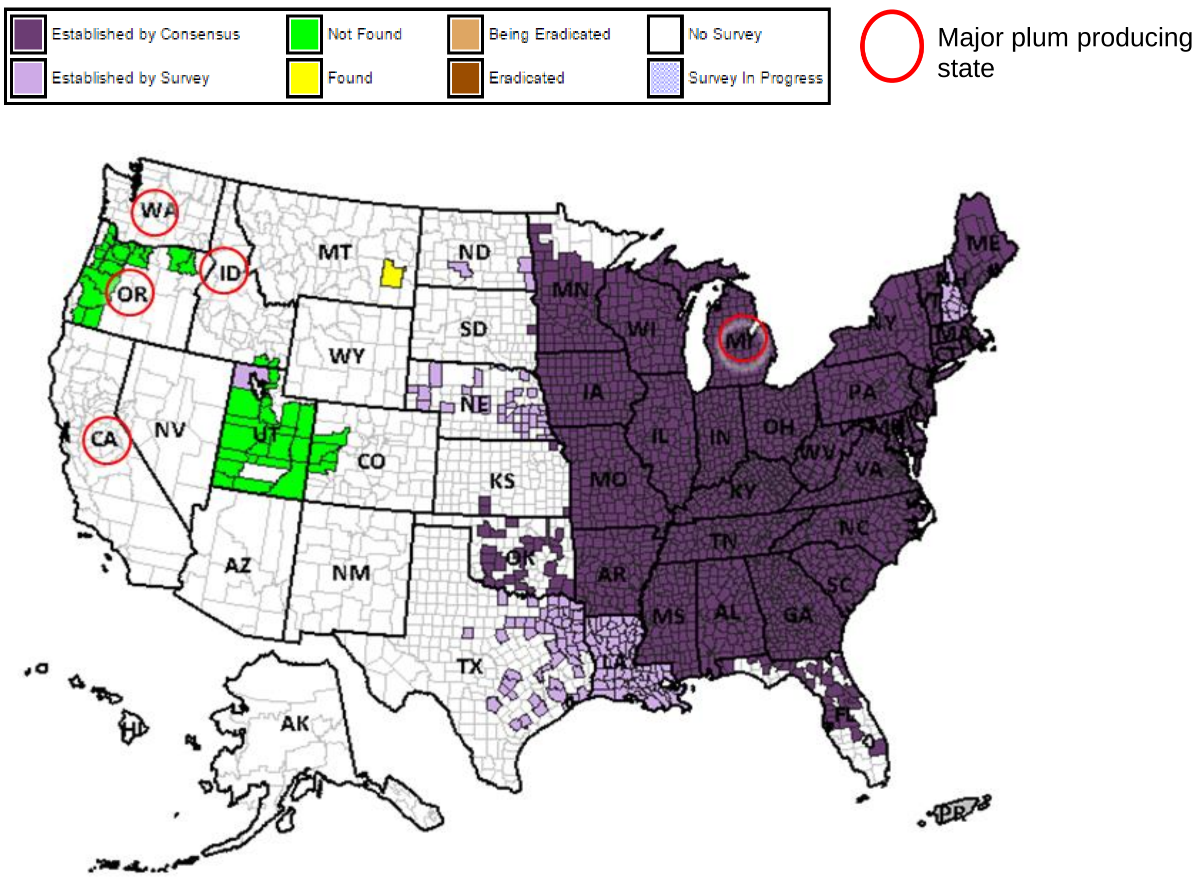
Production statistics	*2006*	*2007*	*2008*	*2009*	*2010*
Plums and Prunes grown for fresh market	3,627	2,234	2,429	2,588	2,356
Plums and Prunes for processing	45	9	-	21	16
Total production Plums and Prunes	3,673	2,243	2,470	2,609	2,372
Exports Plums, Prunes & Sloes	49	17	18	12	14
% of total production exported	1.33	0.76	0.73	0.46	0.59

EuroStat holds a variety of statistics regarding EU imports of fresh fruit and vegetables. Searching the EuroStat database using CN code 0809 4005 (fresh plums), from USA and Canada, revealed that the EU has not imported fresh plums from Canada for at least 5 years whilst only a small, and declining amount, has been imported from USA in recent years (Table C.2.02). This report will therefore move to consider the occurrence of the case study pest, *C. nenuphar*, in the USA.

Table C.2.02: EU (28) imports of fresh plums (CN 0809 4005) from USA and Canada (tonnes) (2010-2014) (Source: Eurostat)

Year	Canada	USA
2010	0	166.1
2011	0	23.4
2012	0	66.8
2013	0	14.4
2014	0	0

Figure C.2.02 shows the reported distribution of *Conotrachelus nenuphar* within the USA. Although fairly widespread in the eastern states, *C. nenuphar* does not occur in the major plum producing States which are found to the west of the USA.



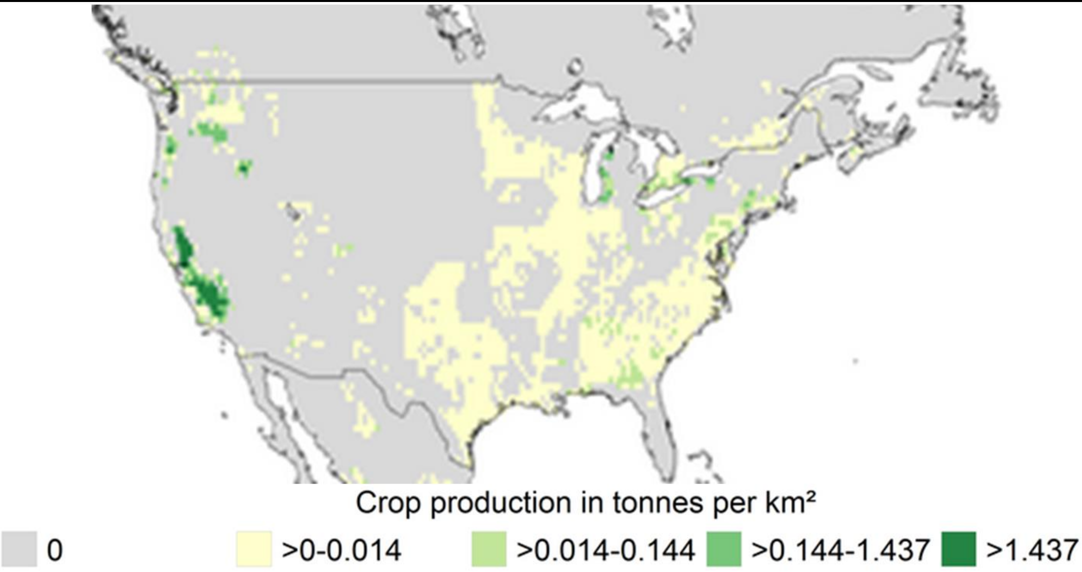
Source: http://pest.ceris.purdue.edu/map.php?code=INASAVA#

Figure C.2.02: Reported distribution of *Conotrachelus nenuphar* within the USA

In the USA, California is the dominant producer of plums. During the three years 2012-2014, almost 90% of total US plum production occurred in California. Mean production was approximately 101,700 tonnes annually. Oregon is generally the next largest producer, followed by Washington, Idaho and Michigan (Table C.2.03) (NASS, 2015).

Table C.2.03: US production of plums within the top 5 plum producing States (Source: NASS, 2015)

State	Year	Area (ha)	Production (tonnes)	% of US production (3 year mean)
California	2012	8,100	104,300	
	2013	7,300	86,500	
	2014	7,300	114,300	
			Mean = 101,700	89.1
Oregon	2012	530	6,500	
	2013	530	6,200	
	2014	530	7,100	
			Mean = 6,600	5.8
Washington	2012	160	3,000	
	2013	160	2,100	
	2014	160	2,300	
	mean		Mean = 2,500	2.2
Idaho	2012	160	2,200	
	2013	160	2,200	
	2014	160	2,200	
	mean		Mean = 2,200	1.9
Michigan	2012	200	100	
	2013	200	1,700	
	2014	160	1,500	
	mean		Mean =1,100	1.0
			National mean = 114,100	100.0



Source: McGill University, http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html
Monfreda *et al.* (2008) http://www.sage.wisc.edu/pubs/articles/M-Z/Monfreda/MonfredaGBC2008.pdf
http://capra.eppo.org/files/maps/plum_5min_prod.png

Figure C.2.03: Plum production regions of USA and Canada (estimated annual production)

Conotrachelus nenuphar does occur in Michigan (Figure C.2.03), the fifth greatest plum producing state, hence the origin of the pathway that presents a potential risk of introducing *C. nenuphar* via stone fruit, specifically plums, into the EU is fresh plums from Michigan.

Most commercial orchards are free from permanent populations of *C. nenuphar* but orchards become infested by adults moving in from adjoining hedgerows and woodlands in the spring (Lienk, 1980).

The next section describes the life cycle of the pest in order to inform a judgement regarding likelihood of infestation at the start of the pathway.

C.3 Pest life cycle: *Conotrachelus nenuphar*

Conotrachelus nenuphar is native to North American where it can be a serious pest of a range of orchard stone fruit crops such as peaches, plums and cherries, and also of pome fruit (apples & pears) (Metcalf & Metcalf, 1993). Following a mark-recapture study Leskey & Wright (2007) determined host preference to be, in descending order, Japanese plum (most preferred), European plum, peach, sweet cherry, tart cherry, apricot, apple and finally pear.

As indicated in Figure C.2.02, in the eastern US the pest is distributed from Maine in the north to midway through Florida in the south. In the north of its range there is one generation per year (north of 39oN). This has been described as the northern strain in which the adults have an obligatory winter diapause, with adults not mating until spring (Smith & Salkfeld, 1964; Hoffman et al., 2004). The southern strain does not require winter diapause but can mate in mid to late summer to produce a second generation, and even a partial third generation in warmer years (Metcalf & Metcalf, 1993; Hoffman et al., 2004).

In northern areas adults overwinter on the ground under fallen leaves and stones. Neglected and uncultivated orchards can provide weedy areas, long grass and other debris that adults find suitable as overwintering sites and such poorly managed orchards tend to suffer greater damage (Campbell et al., 1989). Nevertheless, well managed orchards can still become infested when adults emerge from hedgerows and adjacent woodland and move into host trees in orchards (Metcalf & Metcalf, 1993).

In the region of Michigan (US) and Ontario (CA), adults usually emerge in early summer, once there have been several days with a mean temperature above 15.5oC (Lienk, 1980). Such a temperature occurs occasionally as early as late April or as late as late July (Armstrong, 1958). However, over 90% of adults have usually emerged by the end of the first week in June. After emerging from overwintering sites, adults feed on new tender shoots and leaves of hosts and petals within flower buds before mating. Later as fruit begin to develop adults feed on the fruit (Armstrong, 1958; Lienk, 1980; Metcalf & Metcalf, 1993). However, it is the oviposition punctures that are considered to cause the greatest damage. Following maturation feeding, females chew holes through the skin of developing fruit and lay eggs singly. Females prefer to oviposit on multiple fruit rather than lay multiple eggs in one fruit (Selby & Whalon, 2014). Females oviposit between 32 and 188 eggs (mean of 75) during their lifespan (Armstrong, 1958) although Metcalf & Metcalf (1993) report females laying on average between 145 and 200 eggs. Multiple eggs can be placed separately within a single fruit (Campbell et al., 1989). In other words different females can lay an egg in the same individual fruit. An examination of the pattern of host phenology and infestation levels suggests that C. nenuphar oviposition synchronizes well with the availability of suitable fruit for oviposition (Polavarapu et al., 2004). A heavily infested plum orchard may have up to 35% of fruit damaged by adult feeding (Armstong, 1958). However, more recent literature does not report such levels of infestation and it is assumed that the pest is much better controlled (see Pest Management below).

Eggs typically hatch in 4 to 7 days. Larvae feed on the pulp of host fruit. There are four instars. Larval activity inside infested fruits causes them to drop earlier than un-infested fruit (Levine & Hall, 1977). Fruit that drop early are smaller than fruit that drop later. In a study where plums were experimentally infested with eggs and larvae, fruit that dropped early all contained live larvae, whilst infested fruit that remained on the tree and did not drop early, but were available to be picked and harvested, only contained larvae that had reached the 1st or 2nd instar before dying (Levine & Hall, 1977). Eggs and larvae are crushed by the pressure within an infested fruit as the fruit swells. Hence larvae very often only complete their development in fallen fruit (Lienk, 1980; Metcalf & Metcalf, 1993).

Depending on temperature, larvae develop within 2 to 3 weeks. Larvae exit the fallen fruit and burrow into the soil to form pupae. 12 to 16 days after leaving fruit, pupae are formed (Lienk, 1980) from which adults emerge 2 to 3 weeks later. Adults then continue to feed on fruit for the rest of the summer before searching for overwintering sites during August, September or October. The following spring, adults emerge to repeat the cycle.

C.4 Pest management

Despite its common name (plum curculio), much of the literature concerning *C. nenuphar* management and pest control is in relation to the organism in apple orchards (reviews by Racette *et al.*, 1992 and Vincent *et al.*, 1999) or peaches.

Historically commercial fruit orchards have had difficulty in controlling *C. nenuphar* due to difficulty in the correct timing of pesticide applications (Prokopy *et al.*, 2000). During the 1990s, much research on *C. nenuphar* focussed on developing systems to monitor the behaviour of adults at the edges of orchards and around overwintering sites so as to better inform decisions regarding timing of insecticide applications (Vincent *et al.*, 1999). Nowadays management in plums is achieved through careful timing of insecticides shortly after petals fall from the blossoms or at the first sign of adult feeding damage. A second spray 10 days later is sometimes needed for further control and during cool weather periods; a third application may be needed when a high level of control is desired. An important preventative measure is to destroy fallen (infested) fruit before the adults emerge.

A wide array of insecticide options are available to commercial growers for control of *C. nenuphar*, including neonicotinoids, pyrethroids oxadiazine and kaolin clay (Michigan Plum Growers Association, 2012). Organic producers can use products containing pyrethrin, but the products are much less effective and will require reapplication at three- to seven-day intervals for effective control (University of Maine, 2015).

C.5 Harvesting plums

Plums are climacteric and can ripen rapidly during transit and storage (Anon., 2006) hence plums for the fresh market should be left on the tree until they are mature, but they will continue to ripen after picking. Plums are harvested at a firm ripe stage to allow handling during packing and marketing. Harvest date can be determined by skin colour changes designed to determine maturity for each cultivar. Some cultivars have skin ground colour that is masked by full red or dark colour development during maturation. For these cultivars, flesh firmness is measured for an indicator of maturity (Bates *et al*., 2001). Plums destined for distant markets (as in this case study situation) should be picked at the "firm-ripe" stage (Bhutani & Joshi, 1995) typically 3-7 days before full ripeness to withstand shipping and handling (CABI, 2014).

Plums ripen unevenly so should be harvested in two or three pickings (Bhutani & Joshi, 1995). Plums for the fresh market are harvested by hand and experienced pickers are required (Day *et al*., 2009; British Colombia MAFF, 2004). In California, mechanical harvesters are available for harvesting plums for processing. For example, one type is a shake-and-catch system consisting of a two-part unit, with the main power unit grasping the trunk of the tree, which it then shakes, this dislodges the fruit which falls into the second part of the machine (catchment rails), which rolls the fruit into a collecting bin on a vehicle accompanying the harvester (Huffman, 2012). However, the severity of the shaking can damage the bark on the trees, and plums are damaged when they fall. However, plums for processing do not have to meet the same quality standards as those destined for the fresh market or for export. Attempts to harvest plums mechanically for the fresh market have not succeeded (Bhutani & Joshi, 1995). Plums are packed in shallow crates 10cm – 15cm deep, with no more than 3 layers of fruit (to minimise crushing of the bottom layer). After packing the fruit should be cooled immediately (Bhutani & Joshi, 1995).

C.6 Post-harvest handling

Fresh plums do not lend themselves to long-term storage, nevertheless, most varieties can be held under refrigeration for 2-4 weeks without excessive loss of quality (CABI, 2014) although some varieties can be stored for up to 6 weeks (CargoHandling.com, 2014). Optimum storage conditions for most varieties are -0.5°C and 90% humidity. These conditions result in minimal ethylene production and water loss. A recent study suggested 1-Methylcyclopropene (1-MCP), which inhibits softening in plums, could be used as a medium in which harvested plums are stored above the normal storage temperatures to avoid chilling injury and providing energy and cost savings (Minas et al., 2013). Nevertheless, controlled atmosphere storage has shown to be of limited benefit for extending the storage life of plums. Plums stored for more than 4 weeks usually suffer internal breakdown or rot (CABI, 2014). Brown rot, rhizopus rot, and blue and grey moulds are the most common problems for plums in storage (Rieger, 2006).

C.7 Likelihood of infestation at export

Within EU phytosanitary legislation, plum fruit (actually all *Prunus* spp. fruit) from outside the EU are regulated articles subject to the EC Plant Health Directive (Anon., 2000) as they are potential carriers of harmful organisms of relevance for the entire Community (2000/29/ EC Annex V, B). *Conotrachelus nenuphar* is also listed in Annex 1/A1 of the Plant Health Directive. This means that the organism is regarded as a harmful organism whose introduction into, and spread within, all Member States shall be banned. Hence, before export, plum fruit from Third Countries must be inspected and found free of EU quarantine pests, specifically *Monilinia fructicola* (brown rot of stone fruit).

If consignments are free from quarantine pests, then a phytosanitary certificate can be issued for export to the EU. As noted by GDV (2014) the quarantine regulations of the country of destination (in this case the EU) must be complied with and a phytosanitary certificate will be required for plums from the USA or Canada (or any other Third Country) with the document being enclosed with the shipping documents.

ISPM No. 31 on sampling of consignments, provides guidance as to how many lots (e.g. boxes of fruit), are to be sampled within a consignment depending on the size of the consignment (i.e. how many lots), the degree of pest infestation (5%, 2%, 1%, 0.5% and 0.1%) and the level of confidence required (80%, 90%, 95% or 99%). Sampling size increases as the level of infestation lowers and the confidence required increases.

Imported (and home produced) fruit and vegetables are subject to EU Marketing Standards which align with United Nations Economic Commission for Europe (UNECE) standards. Specific European Union marketing standards exist for plums. The standards may be found in EU Commission Regulation 543/2011 and UNECE (2013). Freshfel Europe (2011) provides a summary of EU marketing standards for plums. In summary, fresh plums are required to be checked for conformity with EU marketing standards for quality and labelling. Plums must be "practically free from pests". "Practically free" is a recognised phytosanitary term used by IPPC and defined in ISPM No. 5 (FAO, 2012) as …"Of a consignment, field or place of production, without pests (or a specific pest) in numbers or quantities in excess of those that can be expected to result from, and be consistent with, good cultural and handling practices employed in the production and marketing of the commodity". Such quality checks in an exporting country could lead to plums being rejected for export to the EU as a conformity certificate is required for all fresh produce shipments destined for the fresh market.

As noted above, plum fruit infested with *C. nenuphar* fall early, prior to harvest or if they remain on the tree at harvest, the larvae or eggs inside fail to develop as they will be crushed by the developing fruit as it swells.

A search of the EU database of interceptions did not reveal any previous interceptions of *C. nenuphar.* Given that the majority of infested plum fruit fall early and would not be harvested for export, and that even infested fruit which is harvested do not sustain live larvae to maturity, there is no data to suggest that the export of plums from the USA provide a realistic pathway for the entry or introduction of *C. nenuphar* into the EU. However, in the interests of this project, it is assumed that there remains a very small chance that a small number of plums do not swell sufficiently to crush eggs or larvae and that some larvae are sustained in harvested plums thus the pathway continues.

In 1994 Mexico halted the importation of peaches from Georgia and South Carolina due to concerns of the peaches carrying *C. nenuphar.* Between 2008 and 2011 the USDA APHIS developed procedures to ensure fruit were free from the pest. The procedures, agreed with Mexico, included field surveys, trapping, packing house inspections, fruit cutting (to detect infested fruit) and post entry inspections (Jenkins *et al*., 2013). Mexico again suspended the import of peaches from South Carolina and Georgia (USA) in October 2011 following interceptions of *C. nenuphar* (Froman, 2014). For the purposes of continuing to examine this pathway, we therefore speculate that it is conceivable that something similar may be possible in plums exported from USA to Europe.

Contribution to model input parameters

Likelihood of infestation at export

Minimum infestation = 0%   Most likely infestation = 0%   Maximum infestation = extremely small but so as to allow the model to at least start, we assume a worst case scenario of 0.1 %? (but perhaps this is too high?)

C.8 Survival during transport

Lan *et al.* (2004) conducted temperature-dependent studies to determine the threshold temperature for development and heat sum (degree days) required for completion of *C. nenuphar* development. The study was conducted at 10 different fixed temperatures, from 11°C to 35°C with observations lasting up to 60 days. No eggs or larvae developed at 11°C. It was found that eggs and larvae required 215.5 degree days (DD) above a threshold of 11.1°C to complete their development from oviposition to peak larval emergence. A threshold of 8.7°C and 442.4 DD was required for pupae to develop to adults.

Fresh plums picked for export should be rapidly cooled after harvest to temperatures below 4ºC (preferably 0ºC) to retard respiratory activity, ripening and decay. At 0ºC and 90%-95% relative humidity, typical storage periods for plums are 3-6 weeks; there being a wide range amongst cultivars (and growing seasons/periods). Between 2°C and 7°C, internal breakdown develops rapidly and is most severe at 5°C. Between -1°C (approx. freezing point for plums) and 2°C the rate of development of internal breakdown is much slower but still does occur.

At storage temperatures above 10°C, internal breakdown will not occur in the fruit, but other quality parameters will start to be affected, such as weight loss leading to shrivelling, rots and moulds and general 'ageing' of the fruit will occur more rapidly (CargoHandling.com, 2014).

South African research workers at the Perishable Products Export Control Board state that most plums cultivars are susceptible to flesh breakdown if exposed to low temperatures (-0.5°C) for longer than about ten days. Research conducted over many seasons led to the development of the dual temperature storage regime, in which the fruit is initially stored at -0.5°C for ten days to derive the maximum benefits of reduced ripening and deterioration rates, followed by an increase of temperature to 7.5°C. This regime has generally proven to be of value, although there have been seasons in which it has not worked satisfactorily (CargoHandling.com, 2014).

Drawing on the study by Lan *et al.* (2004) and taking into account the temperature at which plums are stored and shipped, potentially viable eggs or larvae within infested plum fruit will not develop during storage or transport. The longer plums are held below 11°C, the more likely it is that eggs and larvae will die. Lan *et al.* (2004) reported no larval emergence after 60 days at 11°C. It is assumed this was due to eggs and larvae suffering 100% mortality. Precisely when during the 60 days 100% mortality occurred is unknown, as mortality was not studied or reported in the research.

Table C.8.01: Duration of activities from plum harvesting to distribution noting temperature and impact on development of *C. nenuphar*

Day	Activities	Temperature (°C)	Impact on eggs / larvae
0	Harvesting	Ambient	Nil
0 -1	Grading and sorting then rapid cooling	-0.5	No development of eggs or larvae below 11.1°C. 100% mortality after 60 days.
1-10	Transport, storage or distribution	-0.5 to 2.0	
11 up to 42	Storage & distribution	7.5	

Anon. (2006) suggests maximum storage, transit and shelf life for most plums is 14 to 28 days.

Contribution to model input parameters

Likelihood of surviving transport

Minimum survival = 0% (i.e. 100% mortality)

Most likely survival =?

Maximum survival = 100% (i.e. worst case survival, assume rapid transport and distribution and assume eggs and larvae are not killed. Development occurs again when temperature is above 11.1°C)

C.9 Seasonality and plum varieties from USA

There are fifteen plum varieties typically exported from USA into Europe (UK) as shown in Table C.9.01. The earliest variety (Red Beaut) is marketed in early summer (May), prior to domestic production being available, although peak diversity of imports typically occurs in June and July and supplements domestic production. Imports from USA usually continue until September (FPJ, 2011).

Table C.9.01: Availability of plum varieties from the USA through the year (Source: FPJ, 2011)

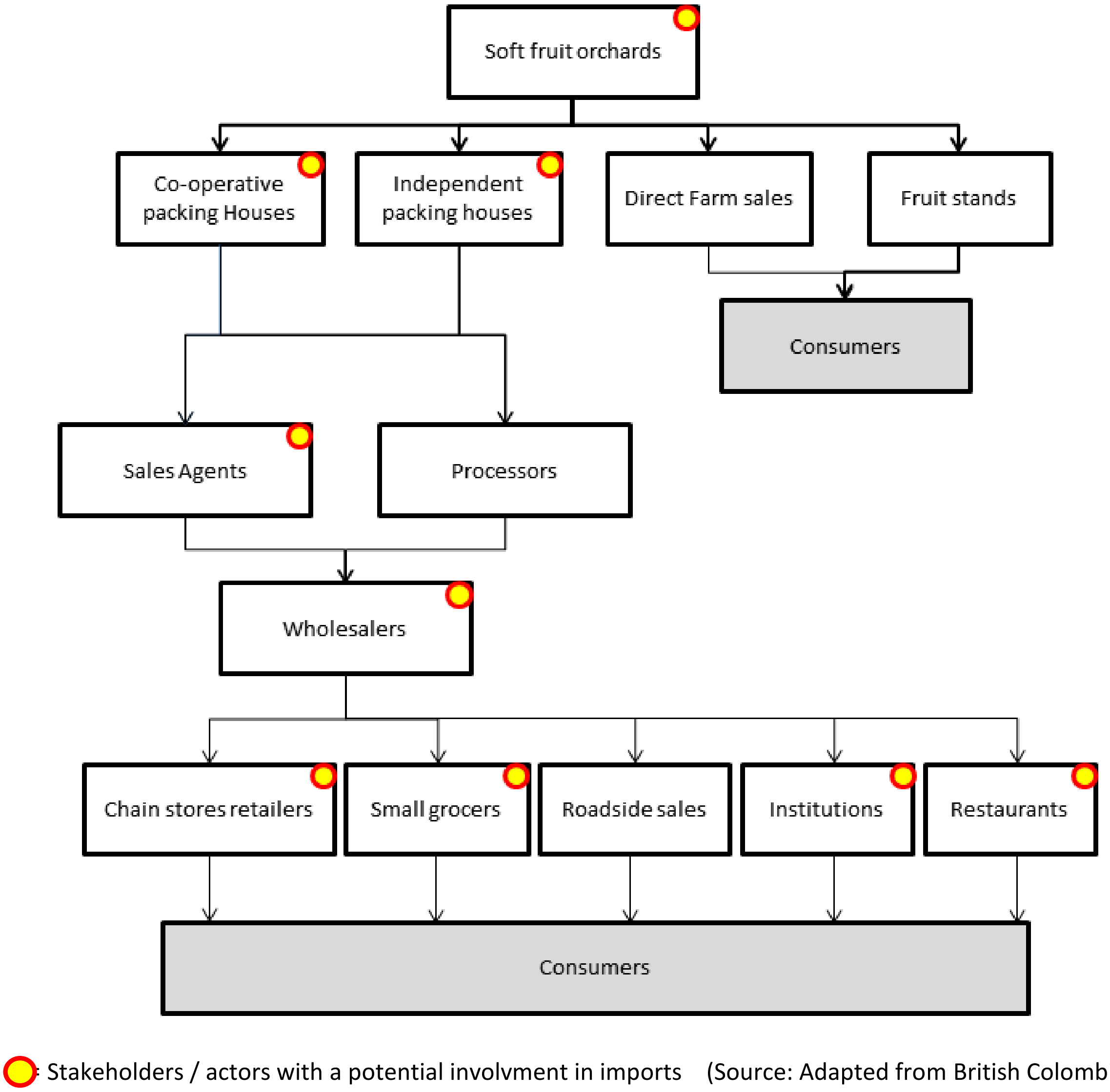
Plum variety	J	F	M	A	M	J	J	A	S	O	N	D
Angeleno								✓	✓			
Autumn Beauty								✓	✓			
Black Amber						✓	✓					
Black Beauty						✓	✓					
Catalina						✓	✓					
Casselman								✓				
Fall Flavour									✓			
Fortune						✓	✓					
Friar							✓	✓				
Hiromi Red						✓						
Howard Sun								✓				
Red Beaut					✓							
Royal Diamond							✓	✓				
Simka							✓					

C.10 Plum uses

Plums may have been one of the first fruits domesticated by humans (Faust & Surányi, 1998) and they have been cultivated and eaten by people in Europe and Asia for thousands of years (Potter, 2012). Plums are valued for the fleshy fruit that is primarily eaten fresh. A small proportion of plums are used for canning and beverage production (Bhutani & Joshi, 1995) and as an ingredient of processed foods. Like other stone fruit, plums are a good source of vitamins and minerals and there is increasing interest in their use as nutraceuticals due to the antioxidant properties of phenolic compounds they contain (Potter, 2012; Ahmad *et al.*, 2013).

In California, almost all European plums are dried for prunes. In other plum producing US states 30-50% are sold to consumers as fresh fruit for consumption; 18-25% are dried; 20-25% are canned, and 1-3% are frozen (Rieger, 2006). However, European per capita consumption of processed fruits and vegetables is already lower than North American consumption. Whilst Europeans consume more fruits and vegetables per capita than North Americans, a larger portion of consumption is fresh, not processed (IBIS, 2014).

Plums can be preserved with sugar when used to make jams, or dried when they are termed prunes. Plums are also used as an ingredient of pies, cakes, tarts, and in confectionery. Plum juice can be fermented into wine or plum brandy. In Asia plums are also pickled. Figure C.10.01 is an example of a typical domestic supply chain that identifies the major stakeholders involved between plum orchards and consumers of the fresh fruit. A plum supply chain is described by DAFF (2012).



(Source: Adapted from British Colombia MAFF, 2004)

Figure C.10.01: Stakeholders operating in the fresh plum supply chain (value chain)

C.11 Fresh fruit for consumption

Once imported, fresh plums destined to be consumed by the public could be assumed to be distributed within the EU according to population density (based on import data, trans-shipments and NUTS2 population density). Larvae surviving in plums at this point can be expected to be (i) eaten if the consumer was unaware of the presence of the larvae; (ii) discarded into domestic waste with a partially eaten plum; (iii) discarded into fruit and vegetable recycling for composting (domestic or organized by local authority) or (iv) discarded outdoors, e.g. if eaten on a picnic.

Contribution to model input parameters
An estimate of the likelihood of infested fruit being discarded following partial consumption by a consumer - see Table 3.1.03 of main report

In Europe, the majority of domestic plum production is for fresh fruit consumption. For example, more than 95% of the production of European plums in the Netherlands is for fresh consumption (Meijer *et al.,* 2013).

C.12 Plums used in processing

There is no data available that identifies the quantities of plums imported from Third Countries that are destined for processing (i.e. there is no CN code with such a commodity description). The supply chain described in Figure 5 shows that plums are processed prior to export. When an industry contact was asked about importing plums for processing, he replied "*Why would you do that? It's expensive to ship plums in cold storage. Why bother bringing in fresh plums for processing, it's just a waste of money*". Given the cost of transport and storage, it is anticipated that the vast majority of plums from the USA (or Canada) are imported for consumption as fresh fruit. Nevertheless, although we have no evidence that fresh plums imported from North America have in the past been specifically imported for processing, there is a small chance that if the market price for fresh plums in the EU falls, then the cost of maintaining imported plums in cold storage becomes unacceptable, and such plums will be shifted into processing. This situation was considered possible in the apple pathway model. However, unlike apples which can be kept in storage for up to 12 months, plums do not have a long storage life and plums are not expected to be held for sufficiently long periods that market prices change very much. Nevertheless, for the purposes of this project, processing imported plums within the EU will be considered.

Contribution to model input parameters

Assume that 95% of imported plums are consumed as fresh fruit (as per Meijer *et al.*, 2013) and 5% are used for processing.

The following data are taken from the plum data frame:

Mean imports from USA = 166 tonnes

Assume 5% used for processing = 8.3 tonnes

C.13 Location of fruit processors

Refer to description of fruit processors at NUTS level in MacLeod (2015).

C.14 Processing activities

Plum fruits are processed into prunes, canned plums, juice, compotes, jams & marmalades and alcoholic beverages. A prune is a variety of plum that is suitable for drying without removing the pit (stone). Plums that are not prunes will ferment when dried with the pit.

C.15 Prunes

The majority of plums that are processed are used to produce prunes. A prune is a dried plum, whose moisture has been reduced to 19-35%. Following harvest plums are loaded into drying tunnels which reduces the moisture content from around 80% to between 17 and 19% within 24 to 36 hours. (The old technique of sun drying could take 10 days). Drying tunnels operate at 74°C. Following dehydration the prunes are graded (by size) and stored for up to 2 weeks to allow "moisture equalization". They are then marketed or used for further processing (Somogyi, 1996).

C.16 Canned plums

Plums are an appropriate fruit for canning although the popularity of canned plums has declined as canned peach, apricot and pear has increased. Somogyi (1996) describes the canning process. It involves washing the fruit, sorting using a belt and vibrating size grader, inspection to remove imperfect fruit, then direct filling into cans or glass jars. Boiling sugar syrup or hot water is added depending if the plums are to be marketed as sweetened or unsweetened. Cans or glass jars are preheated to 88-93°C before sealing. The containers are then sterilized by heating the cans or jars in water at 100°C for 10 to 15 minutes, depending on the size of the container. The cans are then cooled with a water spray to 38°C after processing.

C.17 Plum juice

Unlike apples or oranges, plums do not usually give up a juice upon crushing and pressing and must be treated with a macerating enzyme in order to yield an actual fruit juice. Bates *et al.* (2001) describes the juicing process. It involves sorting the fruit before it is washed and drained. The fruit is then steam heated for about 10 minutes to prepare it for pulping with a very coarse screen to remove the pits. This also helps inactivate the naturally occurring enzymes and prevents darkening. The resultant puree is put through a heat exchanger to cool to 50ºC. An enzyme is thoroughly mixed in and then the mixture is left to stand from six to 12 hours until juice drains readily through a fine cloth. The mix can then be pressed in a manner similar to apple pulp. The subsequent plum juice must be filtered then pasteurized. It can be pasteurized at 88ºC before bottling into bottles or cans preheated to 82 to 85ºC then sealed and cooled. Alternatively, the juice may be filled cold into crown-capped bottles, placed in water and heated to 85ºC for 30 minutes for litre size and smaller bottles. From figures in Dwivedi (2012) approximately 58% of the fresh weight of a plum is pulp or pomace.

C.18 Prune juice

At ~18% moisture, it is impractical to extract juice directly from prunes, so prunes are subjected to an aqueous extraction. Prune juice is made using the "disintegration method". In summary, prunes are washed and vigorously boiled and agitated for 60 to 80 minutes, until disintegrated (or simmered at 82°C for 10 hours). This mash is then pressed, similar to apple pulp (see MacLeod, 2015) or put through a high-speed centrifuge (approximate 4,000 rpm). The resulting juice is allowed to settle, is siphoned off and then must be concentrated before bottling and pasteurization (Somogyi, 1996; Pecoroni, 2008).

C.19 Plum processing and pest survival

In terms of processing providing an opportunity for pests to enter, it is the initial sorting and grading when whole fruit can be rejected prior to more rigorous processing, that presents a potential opportunity allowing pest survival. Subsequent processing activities described above will kill pests contaminating the fruit.

Assuming that there is still a likelihood that the case study pest has survived in fresh plums that have been switched from the fresh fruit market to processing, and that the infested fruit is rejected at the initial stage of processing (sorting to remove damaged and contaminated fruit) then it is how the waste is managed that will influence any pests continued survival.

C.20 Management of food processing residue

In order to meet stringent environmental requirements, modern fruit processing should minimize the amount of by-products and waste, to produce high-quality foodstuffs without polluting the soil, air or water (Barta *et al*., 1997; cited in Monspart-Senyi, 2006). Fruit processing waste is organic therefore decomposes and can be returned to soil. In addition due to its relatively high water content it can be voluminous and often deteriorates quickly.

Fruit processing residues include residuals of fruit, unusable parts of fruits and fruits which do not meet size, quality, or other product specifications and which were intended for human or animal consumption. Fruit residues can have value such as an animal feed source or as a fertilizer for crop production. The majority of plum pomace, produced as a waste product from juicing plums, is used for feeding animals or discarded for land application (Pecoroni *et al*., 2008; Milala *et al.,* 2013).

Fruit processing residues contain sugars that can be converted to ethanol through fermentation. However, its production is expensive and involves fermentation and distillation and is generally uneconomic (Mannapperuma, 2005).

C.21 Plum processing waste as a constituent of animal feed

Plum fibre is a natural co-product made from the plum pomace generated from the processing of plums. Plum fibre is a high quality source of soluble and insoluble dietary fibre and is used in human and animal foods (Marshall Ingredients, 2015). It is reasonable to assume that the residue from each plum processing system can contribute to animal feed. As with the waste from apple processing, further processing of plum pomace is likely to improve its quality, and hence value, of material destined for animal feed by applying any of the five methods listed in Table 7 (Harpster *et al.*, 1993; Brandt & Martin, 1994). Ensiling is particularly favoured as it provides a means of storage which is often a major problem when managing food residues. Additionally, ensiling provides an opportunity for blending with other feed materials to improve the formulation and form a more complete feed mixture. As ensiling involves storage of feed material in an anaerobic environment to encourage fermentation, it will also make survival of any insects contaminating the mixture less likely. The last column in Table C.21.01 provides a comment regarding the likelihood of any insect pests, such as eggs or larvae of *C. nenuphar* (the case study pest) surviving the treatment method.

More recently, Monspart-Senyi (2006) reported pomace being dried and formed into pellets for animal feed. The moisture content and feed value of such products are continuously checked to ensure they are of consistent quality (Bennett, 2002).

Table C.21.01: Treatment methods to improve the animal feed value of food processing "waste" (based on Harpster *et al.*, 1993)

Method	Detail	Likely to cause mortality to insects in waste?
Mechanical	Grind, chop, pelletixe, extrude, screen, roll	Yes. Very likely. Larvae are 7.5 – 9.5mm (Smith *et al.*, 1997a) hence are sufficiently large to be physically and mortally damaged if they enter mechanical treatments.
Heat	Dry heat, roast, micronize, pop, flash dry, dehydrate	Yes. Very likely, temperatures will exceed survivable limits
Chemical	Treat with acid, alkali, or ammonia	Yes. Very likely, pH likely to exceed survivable limits.
Biological	Bacterial cultures, anaerobically digest, compost	Anaerobic digestion – Yes. The anoxic environment will destroy larvae. Composting - some chance of survival if not managed properly (see text below).
Ensiling	Vertical (conventional, air-tight), horizontal (trench, bunker, pit, pile, large bag), round bale (bagged, wrapped)	Yes – anaerobic conditions will destroy larvae.

C.22 Composting

A well-managed composting system will achieve temperatures of 60-65°C for several days and will be effective at eliminating insect pests from infested fruit (review by Sansford & MacLeod, 1998).

However, less well managed systems that do not efficiently turn and combine the components of the compost pile can allow insect pests to survive at the margins of the compost where temperatures do not reach lethal limits (Bishop *et al.* 2002; Keen *et al.*, 2002).

C.23 Land application

"Land application" is a term to describe the destination of by-products or "waste" from food processing. After treatment, residue is applied to land where its fertilising properties can be used. Specifically with regard to fresh fruit processing waste, material can be mixed with sawdust, leaves, soil or compost before being applied onto land using conventional farm machinery (Anon., 2001). In a review by Dhillon *et al.* (2013) 80% of apple pomace was disposed of via composting, landfill or incinerated. It is reasonable to assume that a similar proportion of plum pomace may also be disposed of in this way.

Contribution to model input parameters
Only a small proportion of plums are actually processed in Europe. Most are eaten fresh. Of the volume that is processed, there is no data to show the proportion used in each type of processing. % larval survival during processing = ? No data available Assuming that only infested fruit that are screened out at the start of processing allow larvae to survive, adopt the same approach as for apples. Assume 20% of waste goes to animal feed and 80% goes to land application (composting or land fill) Any pests in pomace waste that is incinerated will be killed. An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via land application (based on Table 7) Landfill = a small fraction will survive. If near the surface of the landfill, birds will feed on waste fruit / pomace, rotting fruit will degrade inhibiting larval development. If buried within landfill, emerging adults will not escape. Composting = as in previous estimate, survival in poorly managed composting system = Guess 20%) An estimate of the likelihood of survival of pests in the residue of processed infested fruit, disposed of via animal feed according to method of treatment (based on Table 7) Mechanical = 0% survival Heat = 0% survival Chemical = 0% survival Biological = ? % survival in poorly managed composting systems. (Guess 20%) Ensiling = 0% survival

C.24 Likelihood of contact with host

For completeness, the model makes an assessment of the likelihood of contact with host plums if adults were to emerge at points along the pathway. As described in the life cycle stage adults emerge to feed on emerging shoots, leaves and buds of hosts when there have been several days with a mean temperature above 15.5°C (see section C.4.). The model therefore needs to recognise when mean temperatures exceed 15.5°C at NUTS 2 regions across Europe. For the purposes of this model, Europe is divided into three zones (northern, central and southern) based on NUTS 2 (Table C.24.01). Section C.27 shows average monthly temperatures at locations in northern, central and southern

Europe, indicating in which months adults could potentially emerge. If a host is at a suitable phenological stage i.e. new shoots are emerging, green leaves are growing, flower buds or fruit are developing, at a time when adults are emerging then contact may be possible (section C.28).

Table C.24.01: Classification of EU Countries/NUTS2 regions into Northern, Central or Southern European Zones

Country	NUTS2	'Zone'
Denmark	all	Northern
Estonia	all	
Finland	all	
Latvia	all	
Lithuania	all	
Sweden	all	
United Kingdom	UKC2,UKD1,UKM2,3,5,6,UKN0	
United Kingdom	all UK NUTS not in Northern Europe	Central
Austria	all	
Belgium	all	
Bulgaria	all	
Czech Republic	all	
France	all FR NUTS2 not in Southern Europe	
Germany	all	
Hungary	all	
Ireland	all	
Italy	ITC1,2,4,ITH1.2	
Luxembourg	all	
Netherlands	all	
Poland	all	
Romania	all	
Slovakia	all	
Spain	ES11,12,13,21	
Croatia	all	Southern
Cyprus	all	
France	FR81,82,83	
Greece	all	
Italy	all IT NUTS not in Central Europe	
Malta	all	
Portugal	all	
Slovenia	all	
Spain	all ES NUTS2 not in Central Europe	

Table C.24.02 summarises the relevant phenology of plum development (first flowering, full flowering and harvesting of fruit) for the three European zones. Data for flowering phenology was taken from

Kemp (1996). Harvesting of plums is correlated with temperature accumulation 30 days after full flowering (Ben Mimoun & De Jong, 1999; DeBuse *et al*., 2010). In Central European countries (e.g. Belgium, Germany, Hungary) plums are generally harvested and marketed in the summer July to September, depending on the variety, whilst in Southern Europe (e.g. Cyprus, Greece, Portugal and parts of southern Italy) early plums can be harvested in May whilst later varieties are still available into October or November (marketing patterns described in FPJ, 2011) (section C.29).

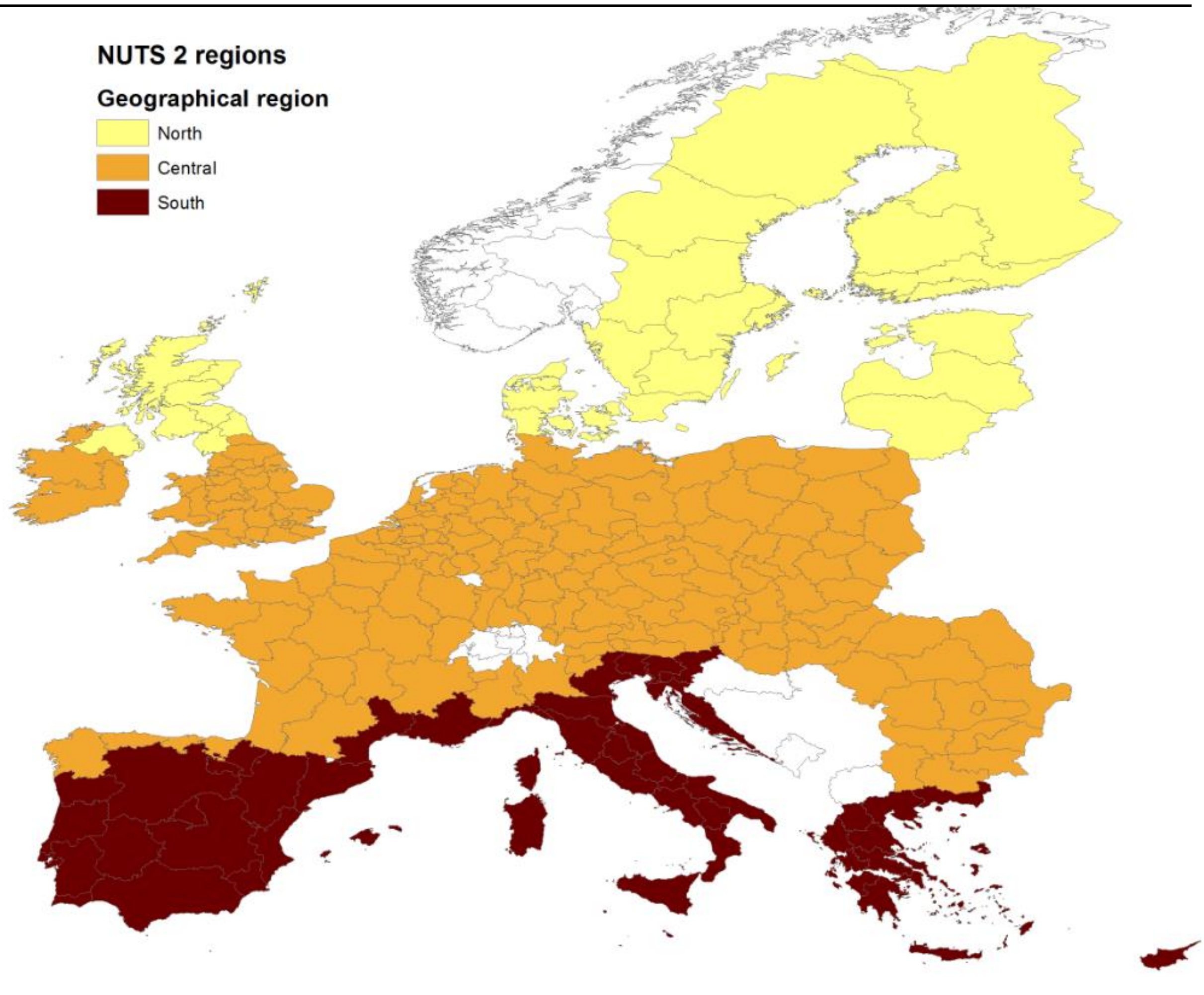


Figure C.24.01: The EU divided into three regions by NUTS2 (Table C.24.01)

Table C.24.02: Approximate timing of events in plum development over European regions to inform model parameters for likelihood of pest contact

European zone	Flowering		Full bloom		Plum harvest	
	Early	Late	Early	Late	Early	Late
Northern	120	140	127	150	185	240
	late April	mid May	early May	late May	early July	late Aug
Central	105	115	115	125	195	260

	mid April	late April	late April	early May	mid July	mid Sept
Southern	85	95	92	105	135	300
	late March	early April	Early April	Mid April	mid May	late Oct

Table C.24.03 indicates the proportion of plum crop estimated to be at a suitable phenological stage to be infested by *C. nenuphar*. The estimate is based on the availability of plum varieties for marketing for each month of the year from a range of European countries representing northern, central and southern Europe (FPJ, 2010). The availability of plum fruit varieties is then shifted forwards approximately 2 months to represent susceptibility of hosts before they are in fruit, and to reflect information in Table C.24.02. The proportion of European fruit susceptible through the year is not weighted by cultivar production or hectarage because FPJ (2010) does not provide production details at cultivar level (section C.29).

Table C.24.03: Proportion of plum "production" (varieties) susceptible to infestation by *C. nenuphar* in three European regions (section C.29)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern				0.12	0.5	0.92	0.33	0.17				
Central Europe				0.12	0.48	0.85	0.63	0.11	0.04			
Southern			0.15	0.59	0.59	0.50	0.22	0.10	0.05	0.05		

C.25 Adult dispersal

Conotrachelus nenuphar is an infrequent flier. Flying represents < 1% of adult activity (Owens *et al.,* 1982; Chouinard *et al.,* 1993). Chen *et al.* (2006) investigated flight performance of laboratory-reared adult *C. nenuphar* using a flight mill system. Flight usually occurred in short bursts. Flight performance varied considerably amongst individuals, but using the median value of total distance travelled (123m per day), adults living for 16 days could potentially fly almost 2km (1,968m). In the study by Chen *et al.* (2006) adults flew between 0.3m and 8,093m. However, because flight mill experiments involve forced flight, they tend to over-estimate flight performance. Dispersal of up to 2km seems reasonable as the most likely model parameter estimate.

Contribution to model input parameters

Adult dispersal by flight

Min = 1m

Most likely = 2km

Max = 8km

C.26 CN codes

Combined nomenclature (CN) codes within which fresh plums are classified

08	CHAPTER 8 - EDIBLE FRUIT AND NUTS; PEEL OF CITRUS FRUIT OR MELONS
0809	Apricots, cherries, peaches (including nectarines), plums and sloes, fresh:
0809 40	– Plums and sloes:
0809 4005	– – Plums

Other CN codes that refer to plums, such as 0812 9070 (preserved fruit), and 0813 4065 (dried fruit) or 0813 5012 (mixtures of dried fruit and nuts) actually specifically refer to sapadillo plums, from the tropical tree *Manilkara zapota* (L.) P.Royen (= *Achra zapota*) which is not the same as the case study plum *Prunus domestica* (European plum) or *P. salacina* (Japanese plum).

C.27 Average temperatures in European regions

Table C.27.01: Average temperatures at locations in northern, central and southern Europe, indicating in which months adults could potentially emerge.

Average daytime temperature (°C) *Note: Threshold for adult to attack plum trees is a few consecutive days above 15.5 °C*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stockholm	-0.7	-0.6	3	8.6	15.7	20.7	21.9	20.4	15.1	9.9	4.5	1.1
London	8.1	8.6	11.6	14.6	18.1	21	23.4	23.1	20	15.5	11.3	8.4
Budapest	1.2	4.5	10.2	16.3	21.4	24.4	26.5	26	22.1	16.1	8.1	3.1
Paris	6.9	8.2	11.8	14.7	19	21.8	24.4	24.6	20.8	15.8	10.4	7.8
Bucharest	1.5	4.1	10.5	18	23.3	26.8	28.8	28.5	24.6	18	10	3.8
Barcelona	13.4	14.6	15.9	17.6	20.5	24.2	27.5	28	25.5	21.5	17	14.3
Rome	11.9	13	15.2	17.7	22.8	26.9	30.3	30.6	26.5	21.4	15.9	12.6
Lisbon	14.8	16.2	18.8	19.8	22.1	25.7	27.9	28.3	26.5	22.5	18.2	15.3
Athens	12.9	13.6	16	20.3	25.3	29.8	32.6	32.3	28.9	23.1	18.6	14.7
Valencia	16.1	17.2	18.7	20.2	22.8	26.2	29.1	29.6	27.6	23.6	19.5	16.8
Malta	16.1	16	17.8	20	24.2	28.5	31.5	31.8	28.4	25.2	21	17.5

Cells shaded pink have mean temps > 15.5°C. If host is at a suitable phenological stage at the same time, i.e. new shoots are emerging, green leaves growing, fruit is developing, then contact is possible.

C.28 Plum phenology

Table C.28.01: Approximate dates of plum flowering (green), fruit development (sand) and harvesting (pink) across three regions of Europe (as shown using Julian days). The time when mean temperature exceeds 15.5°C is shown by crosses (x). Where crosses overlap colours, there is a likelihood that adult *Conotrachelus nenuphar* could contact a plum host

Julian day	5	30	60	65	70	75	80	85	90	95	100	105	110	115	120	125
Month	Jan	Feb	Mar						Apr						May	
North																
Central											x	x	x	x	x	x
Southern					x	x	x	x	x	x	x	x	x	x	x	x

Julian day	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230
Month					Jun						Jul						Aug				
North	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Central	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Southern	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Julian day	235	240	245	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	3:
Month			Sept						Oct						Nov				
North	x																		
Central	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Southern	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		

Plum phenology
flowering (green) fruit developing (sand) fruit harvest (pink)

Adult flight daily temp > 15.5C x

C.29 Plum marketing

Table C.29.01: Plum marketing by month in European regions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern	-	-	-	-	-	-	0.5	0.92	0.33	0.17	-	-
Central Europe	-	-	-	-	-	0.48	0.85	0.63	0.11	0.04	-	-
Southern	-	-	-	-	0.05	0.59	0.59	0.50	0.22	0.10	0.05	0.05

The susceptibility of plums is shifted forwards approximately 2 months to represent susceptibility of hosts before they are in fruit (Table C.29.02), and to reflect information in Table C.24.01.

Table C.29.02: Proportion of plum "production" (varieties & EU MS) susceptible to infestation by *C. nenuphar* in three European regions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern	-	-	-	0.12[a]	0.5	0.92	0.33	0.17	-	-	-	-
Central Europe	-	-	-	0.12[a]	0.48	0.85	0.63	0.11	0.04	-	-	-
Southern	-	-	0.15	0.59	0.59	0.50	0.22	0.10	0.05	0.05	-	-

Note [a]: 25% of next months' proportion assumed susceptible in April to link with potential early flowering (Table C.24.02).

Appendix D – Case study: Wheat from South America and Oceania with potential infestation by *Listronotus bonariensis*

D.1 Introduction

The project had already selected the case study commodities and pests as shown in Table D.1.01.

Table D.1.01: Quantitative Pathway Analysis Lot 1, Food: Case study commodities and pests

Commodity	Pest	Common name	Case study countries
Pome fruit: Fresh apples	*Cydia prunivora* (Walsh) (Lepidoptera: Tortricidae)	Lesser apple worm	Canada, USA
Stone fruit: Fresh plums	*Conotrachelus nenuphar* (Herbst) (Coleoptera: Curculionidae)	Plum weevil	Canada, USA
Citrus: Sweet oranges	*Xanthomonas citri citri*	Asiatic citrus canker	Any country where *X. citri citri* occurs (many countries).
Cereals: Wheat	*Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae)	Argentine stem weevil	Argentina, Bolivia, Brazil, Chile, Uruguay, Australia, New Zealand

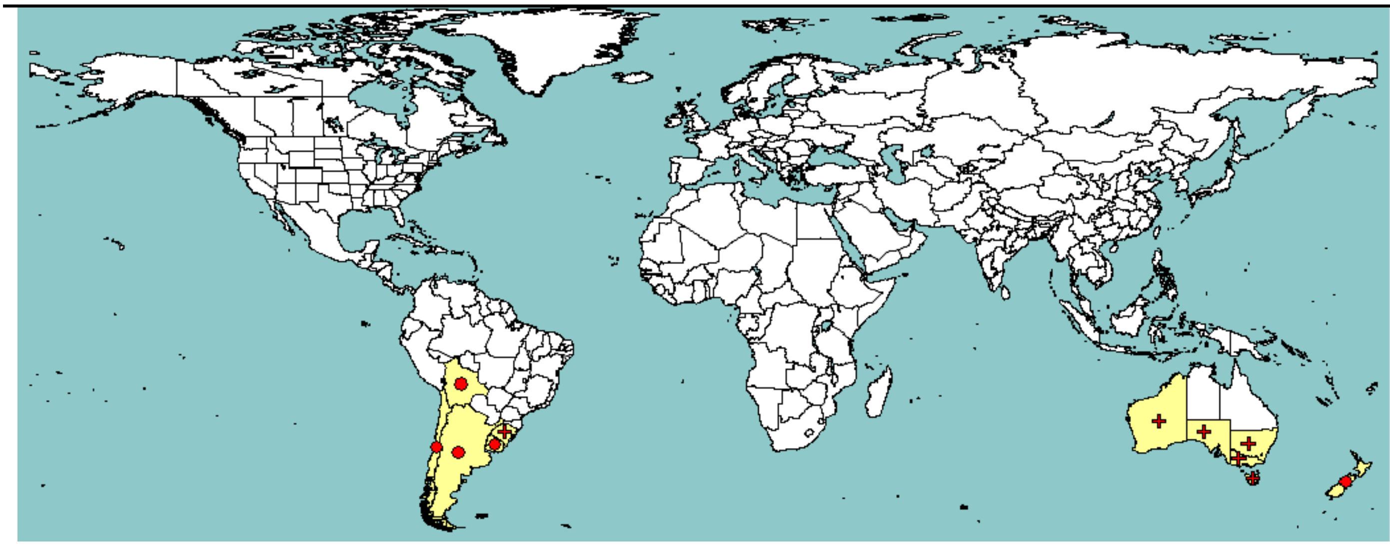
To inform parameterization of the pathway models for each commodity, this report collects information on:

- the distribution of the case study pest at pathway origin,
- exports and pest survival,
- commodity uses,
- commodity processing and waste management, and
- location of processors.

The information is used to provide the rationale for selecting the estimated values for several of the quantitative inputs required in the quantitative models describing the likelihood of pest entry via selected case study pathways on four commodity types (Table D.1.01). The report begins by examining the pathway origin and pest lifecycle.

D.2 Occurrence of pest at origin (South America and Oceania)

The Argentine (or wheat) stem weevil *Listronotus bonariensis* (Kuschel) (Coleoptera: Curculionidae) is a II/A1 EU and an EPPO A1 listed quarantine pest of pasture grasses and cereals native to South America. It is also on the A1 quarantine lists of Turkey and South Africa and is considered to be a quarantine pest in Israel. It entered New Zealand in the 1920s where it has since become a serious pest throughout the country. It has a more limited distribution in Australia (New South Wales, South Australia, Tasmania, Victoria and Western Australia) where it is also a recognised pest. In its native South America, *L. bonariensis* is endemic in Argentina, Bolivia, Brazil, Chile and Uruguay where it is not considered to be a serious pest. However, Gassen (1984) reported that lowered yields of wheat were associated with its presence in crops growing in Argentina and Brazil and that larvae caused shoot mortality, reduction in shoot numbers and diminished yields as a result of feeding on wheat shoots and buds. The pest is also considered to be a problem on sports turf grasses in Australia (Hardy *et al.*, 1979). According to EPPO, *Lolium perenne* (perennial ryegrass), *L. multiflorum* (Italian ryegrass) and *Zea mays* (maize) are the main hosts of the pest whilst *Agrostis tenuis*, *Anthoxanthum aristatum, Festuca pratensis, F. rubra, Lolium* spp*. and Triticum* spp.are considered to be minor hosts of the pest. In New Zealand, *L. bonariensis* is a significant pest of perennial ryegrass in which mining by the larval stages kills both vegetative and flowering tillers of the plant (Pottinger,1961), whilst the adult stages feed on emerging cotyledons from newly sown crops (Goldson & Penman, 1979). Although adults normally only cause minor damage to host plants, an infestation in the region of 200 adults/m² can result in a large larval infestation, leading to significant damage to the crop. Prestidge *et al.* (1991) estimated annual losses resulting from damage caused by the pest in New Zealand to be in the region of 78-251 million New Zealand dollars



Legend: ● Present + sub-national presence (EPPO PQR)

Figure D.1.01: World distribution of *Listronotus bonariensis*

D.3 Pest life cycle: *Listronotus bonariensis*

Adults mainly feed at night on leaf blades and lay their eggs in small clusters in the leaf sheaths surrounding the main stem of the host. Each female can produce up to 37 eggs over a 40 day period, depositing from one to six eggs at each oviposition site. Depending on environmental conditions the eggs can take from 9 days to more than 30 day to hatch with temperature having a major influence on both time to hatch and subsequent larval development (Ostojá-Starzewski, 2011). Newly emerged larvae feed on the crown of the plant and four subsequent larval instars develop over a period of 14-66 days with the duration principally being determined by temperature. Fully developed larvae bore an exit hole in the stem and drop to the ground where they pupate just below the soil surface for 7-15 days after which adults emerge. Adults live for between 62 and 179 days with an average of two generations per year in New Zealand (Ostojá-Starzewski, 2011).

Second (and third) generation adults enter reproductive diapauses in the autumn and cease to lay eggs. These adults over-winter in plant litter on the soil surface or within the crown of the host plant and become active again the following spring, when they mate and start the cycle over (Ostojá-Starzewski, 2011).

D.3 Phenology

Ferguson *et al.* (1994) suggested that heat accumulation based on the number of degree days above 10°C (mean maximum temperature + mean minimum temperatures per month -10°C multiplied by number of days per month) was a major determinant of the number of generations of the pest that could be completed in a single year. They later estimated a generation time from egg to adult of approximately 360 DD above10°C in Otago, New Zealand (Ferguson *et al.*, 1996). Earlier laboratory studies (Barker, 1988) established threshold temperatures for different development stages of the pest and estimated the number of degree days above these threshold temperatures to complete each stage of development (Table D.3.01) and suggested a requirement for 454 degree days to complete the life cycle from egg to adult.

Between 90-100% of eggs hatched at temperatures between 16.5 and 25°C. This was reduced to 83% at a temperature of 30°C. Temperature was also a determinant of survival of eggs larvae and pupae (Table D.3.02) with no survival of any of these life-cycle stages at 10°C and reduced survival of eggs and larvae, but not pupae, at 30°C (Barker, 1988).

Table D.3.01: Threshold temperatures and degree days required to complete development stages on *L. bonariensis*

Stage	Threshold temperature (°C)	Degree days above threshold temperature requires to complete developmental stage
Egg	10.1	83
Larva	9.8	189
Pre-pupa	11.1	40
Pupa	10.4	172
Egg to adult	10.2	454

Table D.3.02: Effect of temperature on mean percentage survival of eggs, larvae and pupae of *L. bonariensis*

Temperature °C	Eggs	Larvae	Pupae
10.0	0	0	0
16.5	91.0 (2.5)	27.1 (6.4)	45.0 (11.1)
20.6	97.5 (1.4)	40.4 (6.8)	75.0 (9.7)
24.9	98.7 (0.9)	45.3 (6.8)	73.7 (10.1)
30.0	83.4 (3.2)	21.3 (5.2)	70.0 (10.2)
Source: Consolidated data from tables 1and 3 (Barker, 1988). Standard Errors in brackets			

At research sites in the southern South Island of New Zealand overwintering female *L. bonariensis* were generally reproductive between September and December/January after which the percentage of reproductive weevils declined rapidly as *L. bonariensis* enters a state of reproductive diapause in Autumn, induced by a photoperiod of 12.3h light:11.7h dark (Goldson 1981, Ferguson *et al*. 1996) The main egg laying period occurred in October/November and peak emergence of adults was recorded between January and March at most study sites whilst occasionally extending to April at other sites. The percentage of reproductive females declined rapidly at all sites in late summer indicating that newly emerged female weevils did not generally become reproductively mature until the following spring. At one site however, some eggs were laid in February and low numbers of teneral second generation weevils were recorded in May or June.

In Canterbury, New Zealand, Pottinger (1961) showed adults to have high overwintering survival (50-60%) in Manawa ryegrass, considered to be a particularly favourable host plant for the pest, as well as significant adult flight, from late August to late April, providing the temperature was > 16°C, the wind speed < 8mph and the relative humidity < 64% (Pottinger 1966). However, in a later study Prestidge and van der Zijpp (1985) reported negligible flight activity amongst 2 generations in central North Island, NZ.

Goldson *et al*. (1999a), in studying dispersion of *L. bonariensis,* found that predisposing conditions for flight were above 19°C, relative humidity below 81% and wind speed below10.8 km per hour, meaning that flight is restricted to the summer months of December to February/March in the north of New Zealand. Barker *et al*. (1989) recorded flight between August and May in Waikato where mean maximum temperatures in winter rarely fall below around 17°C.

They also found that only a proportion of adults were capable of flight with partitioning between reproductive and dispersive ability among individuals in the population. The proportion of adults capable of flight also varied greatly from generation to generation and laboratory experiments indicated that reduction of crowding was correlated with a degeneration of flight muscles and a resumption of reproductive activity.

The high migratory potential of the adults means that pastures of any age can harbour large infestations, with newly-sown pastures being most seriously affected, especially in dry seasons.

To inform the model regarding likelihood of adults coming into contact with hosts. Were adults to emerge from the pathway, estimates regarding the movement capacity of adults are required. Following a thorough literature search no specific records of flight distances were found. In such circumstances information from related species can be used as a "next best" estimate. Working in the USA on *Listronotus maculicolis* (annual bluegrass weevil) Niemczyk (2012) reported that walking was the primary means of travel although some flight had been observed.

D.4 Control of *Listronotus bonariensis* at country of origin

The description below relates to control of *Listronotus bonariensis* in New Zealand. *L. bonariensis* is not considered to be a serious pest in its native South America, possibly due to natural enemies. There are few readily available publications describing its management within South America.

Listronotus bonariensis is difficult to control with insecticides and whilst a number of products are available that will kill adult weevils, pastures can be rapidly re-infested. The larvae also generally live within the plants on which they feed and are therefore protected from most insecticides (Pottinger *et al.* 1984). The adult weevils' dispersive capability also limits the effectiveness of control using insecticides (Goldson *et al*., 1999a, b) and their use is not generally economic due to the relatively low returns from growing pasture crops. The use of systemic insecticides, as well as the timing of sowing to ensure that emergence occurs after the start of diapause for the insect, have both been investigated to assess effectiveness in reducing damage to crops (Goldson & Penman, 1979) but have not generally been adopted in pasture crops because of the low cost effectiveness. However, as *L. bonariensis* has on occasion been considered one of the major pests of barley, wheat and oats in parts of New Zealand (Cromey *et al.,* 1980), the use of systemic insecticides may have a role in controlling the pest in these crops.

In the early 1980s a fungal endophyte *Neotyphodium lolii,* present in perennial ryegrass plants, (*L. perenne*) was shown to confer resistance to *L. bonariensis* (Prestidge *et al*., 1982) leading to improved management strategies for the weevil (e.g., Prestidge *et al*., 1985; Fletcher & Easton, 1997). The resistance is based on the antifeedant pyrrolizidine compound, peramine (Rowan & Gaynor, 1986). However, other alkaloids associated with *N. lolii* have been found to cause ryegrass staggers (Fletcher & Harvey, 1981) and other effects detrimental to stock (e.g., Fletcher & Easton, 1997).

The endoparasitoid *Microctonus hyperodae* (Hymenoptera: Braconidae, Euphorinae) which has co-evolved with *L. bonariensis* in South America was shown to partially control the pest after its introduction to New Zealand in 1991 (Goldson *et al*., 1993). The parasitoid is now widely distributed throughout New Zealand (e.g., Goldson *et al*., 1994) and management of *L. bonariensis* in New Zealand is now based on the interactions between *N. lolii*-infected ryegrass and *M. hyperodae.*

D.5 Likelihood of infestation at harvest

In New Zealand, wheat is normally sown in the autumn (April to June) and harvested in summer (December to February) when the weather is sufficiently dry for easy harvesting. In South Otago, Southland, and the North Island, it is usual to sow wheat in late winter or spring (August or September) and harvest in March/May.

Overwintering females of *L. bonariensis* are generally reproductive in spring/summer (September – December/January) with an egg laying period around October/November. Peak emergence of adults occurs in mid to late summer between January and March/April, coinciding with the main harvest period in parts of the wheat growing regions of the country. Contamination of harvested grain by adult *L. bonariensis* is, therefore, likely to occur in some areas.

D.6 Harvesting, sorting and storing wheat grain

The usual method of harvesting is to head the crop directly with a header harvester and bag the grain. In the drier districts handling of the grain in bulk, both at harvest and for storage, is more common. In bulk handling the grain should be dry enough to prevent heating in storage. In districts where weather is less favourable for harvesting a large quantity of grain may be spoilt because it cannot be harvested in dry conditions, and thus grain driers are being increasingly used to dry the wheat after harvest and before storage.

Seed for sowing is treated differently. It is checked for purity and quality by the exporter before being inspected PPO. It is then packed in sealed bags or wooden crates which are weighed both before shipping and on arrival in the importing country. The consignment is then inspected before being transported by road or rail to the seed wholesalers where it is weighed and repacked into smaller units ready for sale. Losses during transhipping and transport of such seed are likely to be very small, and the quality and plant health inspections in both the exporting and importing countries, are likely to markedly reduce the possibility of *L. bonariensis* being introduced by this route. The small waste stream generated during these procedures is normally sent to landfill or processed for animal feed

D.7 Wheat grain for export

The transport chain of wheat from countries in which *L. bonariensis* occurs begins after harvest when grain, often from multiple growers is transported to the exporters' storage facilities. Dry grain (< 15% water content) is stored at temperatures below 20°C, at around 70% relative humidity and with adequate ventilation. Storage facilities are normally licensed and subject to regular inspections (at least in Australia and NZ). The plant health inspectorate takes representative samples of the stored commodity and issues a phytosanitary certificate if it is free from pests and diseases which have quarantine status in the EU. Minor pests may be allowed providing their numbers are within tolerance limits specified by the importing country.

Import of wheat grain into EU Member States must be inspected at origin for compliance with phytosanitary and quality requirements.

Most wheat imported into EU countries in recent years originates in America and Canada, where *L. bonariensis* does not occur. Grain consignments from countries where the pest is endemic are inspected prior to shipment and the quantity of grain exported is normally comparatively low. Grain is also inspected on arrival at the destination port prior to transhipment or transport to the processing plant. Thus the likelihood of L*. bonariensis* escaping detection is considered to be low.

Contribution to model input parameters

Likelihood of infestation at origin just prior to export

Factors to consider: Adult emergence coincides with main harvest period therefore likely to get some contamination of grain. Grain for export is inspected. No studies have been found that quantify the likelihood of inspectors detecting L. *bonariensis* in harvested grain. However, procedures to remove foreign matter together with plant health inspections would be likely to detect infestation levels at low levels provided the pest was evenly distributed throughout the consignment. No evidence to contradict this assumption has been found. *L. bonariensis* has not been intercepted in grain.

However, *L. bonariensis* have been found (dead) as contaminants of *L. perenne* seed from New Zealand. The seed would have been inspected prior to export, so there does remain a chance that some infestation of exports may remain undetected.

Conclusion: An estimate of the likelihood of *L. bonariensis* escaping detection and proceeding along the pathway is needed. Given effective screening, quality and PH inspections, it reasonable to assume that only infestation at most below 0.5% remains undetected.

D.8 Shipping wheat grain

Within a fixed time period after inspection the grain is transported to the docks and loaded onto bulk carriers for export, the holds of which are inspected before the grain is loaded. The temperature and humidity in the hold are normally kept below 20°C and 15% respectively both to reduce the growth of moulds and to avoid germination of the wheat. For this reason, bulk grain is often dried before shipping. Once the wheat has begun to germinate it can no longer be used for the production of flour and must be used for animal feed or in the brewing industry.

Import of seed for the food, feed and industrial sectors is virtually always in bulk by ship. Quantities of wheat imported to the EU each year are normally determined by shortfalls in the domestic supply after poor harvests and depletion of stocks held at ports wholesalers and processing plants. Some high quality wheat is imported for admixture with domestically grown wheat to produce a premium product.

Bulk grain is generally shipped to specific ports in EU countries which have the capacity for unloading, transhipment and storage. The quantity shipped is greater than that ordered to allow for shrinkage of grain and losses due to spillage during transport and handling. A typical wheat supply chain is illustrated in section D.27.

D.9 Survival of case study pest during cold storage and shipping

L. bonariensis is a pre-harvest pest of plant species within the Poaceae, with adults feeding on the leaves and laying their eggs in leaf sheaths. There are no reports of feeding and egg-laying on seed of susceptible plants and, consequently, the presence of adult weevils in grain shipments is probably a consequence of contamination during harvest. There are no reports of females laying eggs on stored grain although, in the absence of growing plants, this cannot be discounted.

Survival of adult weevils for between 62 and 179 days (Ostojá-Starzewski, 2011) suggests that they can readily survive the journey time of 30 to 40 days in bulk cargoes, at temperatures below 20°C and around 70% relative humidity, from South America and Australasia where the pest is endemic. As adults are present during the harvest season in New Zealand they are likely to contaminate grain during harvest and storage and, unless detected during pre-export inspection, are likely to survive the journey.

Contribution to model input parameters

An estimate of the likelihood of bulk grain remaining infested after shipping is needed. A conservative estimate would be to assume grain is in storage at the port of origin for 2-4 weeks and the receiving port 4-8 weeks. Assuming that the shipping time was ~ 5-6 weeks then total storage time would be 11 – 18 weeks. Reported figures for survival of adult *L. bonariensis* range from 62-179 days (~9-26 weeks) suggesting that a large proportion of undetected *L. bonariensis* would survive storage and transport.

Conclusion: A conservative estimate is that infestation rates would diminish after 11-18 weeks storage provided egg laying by females did not occur.

D.10 EU import regulation for import of wheat from third countries

Wheat imported into the EU requires a phytosanitary certificate with an additional declaration stating "Consignment complies with Annex II.A.I, point 18 of EC Plant Health Directive 2000/29/EC" meaning that consignments must be free of *L. bonariensis* on seeds of *Cruciferae*, *Gramineae* and *Trifolium* spp., originating in Argentina, Australia, Bolivia, Chile, New Zealand and Uruguay. Brazil is not listed despite the presence of the pest.

The quality of consignments of wheat entering the EU is covered by Commission Regulation (EU) No 642/2010 (on rules of application (cereal sector import duties) for Council Regulation (EC) No 1234/2007) which specifies grading criteria for common wheat based on the protein content, specific weight, miscellaneous impurities (Schwarzbesatz) content and vitreous grain content (Table 4). These parameters must be determined on each lot imported unless an official recognition procedure has been established for the quality certificates issued by the exporting country. In this case, 3% of grain shipments entering each port during the marketing year must be sampled.

Table D.10.01: Classification standards for imported products (on the basis of a moisture content of 12 % by weight or equivalent).

Product	Common wheat and spelt[1] excluding meslin Durum wheat Flint maize	Durum wheat

CN code	ex 1001 91 20 and ex 1001 99 00			1001 11 00 and 1001 19 00		
Quality[2]	High	Medium	Low	High	Medium	Low
Minimum protein percentage (-0.7)[3]	14.0	11.5	-	-	-	-
Minimum specific weight kg/hl (-0.5) [3]	77.0	74.0	-	76.0	76.0	-
Maximum impurity percentage (*Schwarzbesatz*) (+0.5) [3]	1.5	1.5	-	1.5	1.5	-
Minimum vitreous grain percentage (-2.0) [3]	-	-	-	75.0	62.0	-
5. Maximum flotation index	-	-	-	-	-	

[1] Including husked spelt. [2] The methods of analysis provided for in Part IV of Annex I to Regulation (EU) No 1272/2009 are applicable. [3]Tolerances

D.11 Classification codes for wheat shipments

The Eurostat statistics database has nine classifications for wheat traded on the domestic and international markets. The bulk of wheat imported into EU states from countries where *L. bonariensis* is endemic is in the category spelt, common wheat and meslin (G10019099). Small amounts of durum wheat and wheat seed for sowing are also imported mainly from North America. Table 5 lists the categories of wheat distinguished in the Eurostat database.

Table D.11.01: Eurostat codes used to classify wheat

Class	Division	Group	Class	Description
G				Total for countries whose data are confidential, broken down by origin and/or destination
	10			Cereals
		01		Wheat
			1000	Durum wheat
			1010	Durum wheat seed
			1090	Durum wheat (excl. Seed)
			1100	Durum wheat seed for sowing
			1900	Durum wheat (excl. seed for sowing)
			9010	Spelt for sowing
			9091	Common wheat and meslin seed
			9099	Spelt, common wheat and meslin (excl. seed)
			9110	Spelt seed for sowing
			9120	Seed of common wheat or meslin, for sowing
			9190	Wheat seed for sowing (excl. Durum, common wheat and spelt)
			9900	Wheat and meslin (excl. Seed for sowing, and durum wheat)

D.12 Main ports of entry of bulk grain into the EU

Table D.12.01 lists all EU country ports handling grain from countries where *L. bonariensis* occurs and Appendix 1 gives an indication of quarterly imports of bulk grain imported through those ports between 2010 and 2013. Data for the breakdown of dry bulk agricultural products into their separate categories is not distinguished in the Eurostat database and so it is not possible to obtain the quantities of wheat in such consignments from this database. However, it is probable that those ports handling most of the bulk grain also handle most of the wheat imported into Europe. These include Ghent, Hamburg, Amsterdam, Rotterdam Nantes, Immingham, Liverpool and Belfast. Bulk grain imported into Italy and Spain is handled by a number of ports.

Figure D.12.01 shows the total imports of spelt, common wheat and meslin (excl. seed) wheat from Argentina, Australia, Brazil, New Zealand and Uruguay between 2005 and 2012. Imports from other South American countries where the pests is endemic were zero or negligible during this period. No imports were registered for 2012 to 2014.

After arrival at the port of entry the grain is unloaded either by crane, conveyor or Siwertell screw and held in storage silos prior to loading onto lorries or rail trucks for transport to processing plants. In some of the larger ports grain is processed within the port and only the products of processing are transported to wholesale merchants. This is a characteristic of some of the larger agro-industrial companies in which a level of vertical integration has been achieved. Each consignment is inspected by the importing country NPPO inspectorate prior to release from storage at the port.

During unloading from the ship, transport to storage and loading on lorries and/or railway freight trucks for transport to the processing plant there is a significant risk of spillage of grain and escape of any live pests that remain undetected after inspection.

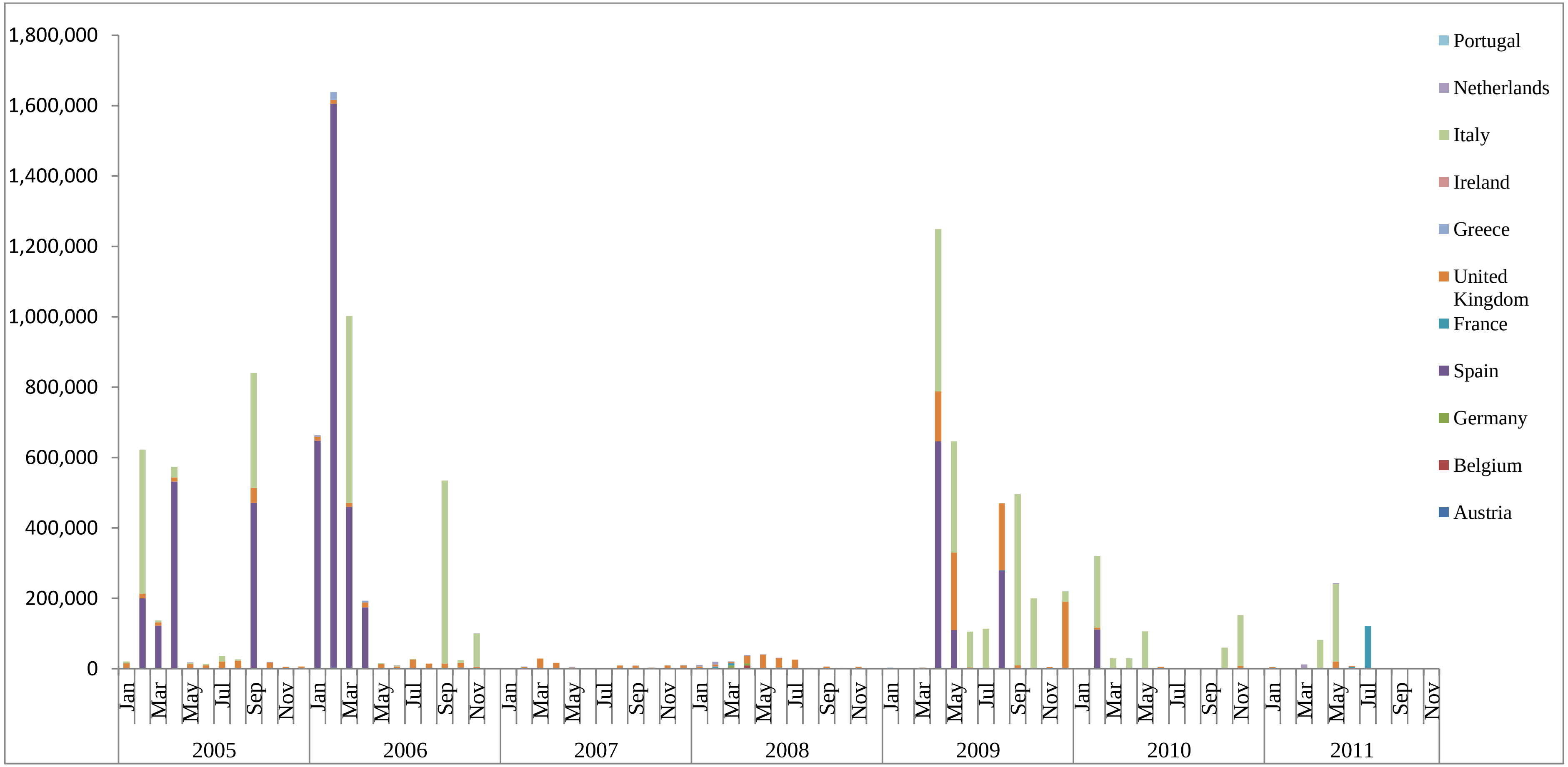
Table D.12.01: Main EU entry ports for bulk grain shipments (NUTS2 code in brackets, NUTS1 for UK)

Belgium	Antwerp (BE21), Ghent (BE23)
Bulgaria	Burgas (BG34), Varna (BG33)
Croatia	Ploce (HR03), Split (HR03)
Cyprus	Larnaka (CY00), Lemesos (CY00)
Denmark	Fredericia (Og Shell-Havnen) (DK01)
Estonia	Tallin (EE00)
France	Bordeaux (FR61), Brest (FR52), Le Havre (FR23), Lorient (FR52), Nantes St Nazaire (FR51), Sete (FR81)
Germany	Brake (DE94), Hamburg (DE60)
Greece	Chalkida (EL12)
Ireland	Cork (IE02), Dublin (IE02), Limerick (IE02)
Italy	Ancona (ITI13), Bari (ITF4), Chioggia (ITH3), Napoli (ITF3), Oristano (ITG2), Pozallio (ITG1), Ravenna (ITH5), Salerno (ITF3), Savona (ITC3), Trieste (ITH4), Venesia (ITH3)
Latvia	Liepaja (LV00), Riga (LV00)
Lithuania	Klaipeda (LT00)
Malta	Valetta (MT00)
Netherlands	Amsterdam (NL32), Rotterdam (NL33), Vlaardingen (NL33), Velsen (NL32), Vlissingen (NL34)
Poland	Gdansk (PL63), Gdynia (PL63), Swinoujscie (PL42) , Szczecin (PL42)
Portugal	Leixões (PT11), Lisbon (PT17), Setubbal (PT16)
Romania	Constanta (RO22)
Slovenia	Koper (SI02)
Spain	Barcelona (ES51), Bibao (ES2), Cadiz (ES61), Cartegena (ES61), Genoa (ITC3), Guijon (ES12) , Huelva (ES61), La Coruna (ES11) , Las Palmas (ES70) , Malaga (ES61), Marin Pontevedra (ESI1) , Santander (ES13) , Tarragona (ES51), Valencia(ES52), Villagarcia (ES11)

UK	Belfast (UKN0), Bristol (UKK1), Clydeport (UKM2), Immingham (UKE1), Liverpool (UKD7), London (UK12), Londonderry (UKN0), Southampton (UKJ3)

Note: NUTS2 codes in brackets.

Figure D.12.01: Total imports of spelt, common wheat and meslin (excl. seed) wheat from Argentina, Australia, Brazil, New Zealand and Uruguay between 2005 and 2012 (KG x 100)



D.13 Seasonality of wheat imports from South America and Oceania

Wheat grain is imported into EU Member States when local supplies are insufficient to meet requirements, particularly when unfavourable weather leads to low harvests in Europe (June-August) and when supplies are available from third countries with harvest periods falling outside those of Europe (Table D.13.01 and Figure D.12.01).

Table D.13.01: Main wheat harvest months in selected EU MS

EU Member State	**Harvest period**
Austria	July-August
Belgium-Luxembourg	July-August
Bulgaria	June-August
Czech Republic	July-August
Denmark	July-August
France	June-August
Germany	July-August
Greece	May-August
Hungary	June-July
Italy	June-August
Netherlands	July-August
Poland	July-August
Romania	June-July
Slovakia	July-August
Spain	June-July
Sweden	August-September
United Kingdom	July-August
Oceania	
Australia	October-January
South America	
Argentina	November-January
Brazil	November-January
Chile	December-January
Uruguay	December-January

Source: Adapted from *World Wheat Statistics*, International Wheat Council

D.14 Seed spillage along the trade pathway and risk of escape of L. bonariensis

Published research related to plant health risks associated with imported wheat (or other) grain during transhipment or transport to storage or milling/processing facilities appears to be lacking. Nevertheless, research conducted on spillage of oilseed rape seed during landing at ports and subsequent transport to processing plants can give an indication of possible losses through spillage during importation of wheat grain, as well as the risk of escape of quarantine pests associated with such imports.

Most of the work in this area has been carried out on bulk shipments of imported oilseed rape (*Brassica napa*) to assess the likelihood of genetically modified (GM) seed escaping during unloading from maritime vessels, transhipment and transport, from the ports to the processing facilities. Saji *et al*. (2005) investigating presence of GM *B. napa* at 143 locations at several Japanese ports, roadsides and riverbanks were able to detect transgenic *B. napus* growing at five out of six ports and along two of four main roads leading from the ports. Since transgenic oilseed rape has not been commercially grown in Japan they concluded that the plants originated from seed spillage during unloading, transhipment and transport.

In another study feral *B. napus* was discovered around all 13 Japanese harbours that import rapeseeds from overseas. In addition, two kinds of herbicide-tolerant *B. napa* (glyphosate- and glufosinate-tolerant) were discovered growing along the route from the port to processing plant some 40 km from the port. It was concluded that the source of the plants was from seed spillage during transportation by trucks from harbours to oil factories and other processing facilities (Kawata *et al*., 2009). In a study of the spillage of seed from vehicles, also in Japan, von der Lippe and Kowarik (2007a) found that three species of arable crops, wheat (*Triticum aestivum*), rye (*Secale cereale*) and oilseed rape (*Brassica napus*), were among the most frequent species deposited. They concluded that seed dispersal by vehicles is the major driver in the recruitment of roadside populations of arable crops, providing a possible escape route for GM crops, and that risk management should be directed at curbing transport losses of such crops. Similar results have been obtained along roads in Germany (von der Lippe and Kowarik, 2007b) and the UK (Crawley & Brown, 1995), along railway lines in Switzerland (Hecht *et al*., 2014) and both road and railway lines in Canada (Yoshimura *et al*., 2006).

Tamis *et al*. (2009), in a review of transport chains and seed spillage of GM crops, suggested that in the oilseed and animal feed chains, spillage of seeds can occur at any point in the early part of the chain involving transhipment or transport including:

- transfer from vessel to quayside storage silo (either within or outside the processing site)
- road transport from storage silo to production silo at the processing site, with loading/unloading at each end
- disposal of seed-cleaning residues and waste arising during process changes

They suggested that the greatest losses were probably associated with bulk transhipment prior to transport to the processing plant with a fraction spilled into the harbour water (Schuttelaer, 2009) and a smaller fraction along the roads during transport from the port to the processing plant. Sources from the trade estimated that between 0.1-0.3 percent to 2-3% of rapeseed was lost during these stages, with the lower estimate based on estimates of the differences before and after weighing at the processing plant and the higher estimate relating to losses relating to the animal feed industry where oil seed rape seeds are processed in a more open system.

In surveys around ports of entry, processing plants and roads from ports to processing plants they also detected large numbers of flowering rapeseed plants which trade sources reported were derived from wind-dispersed seed lost during loading and unloading operations. Losses also occur from spillage on the conveyor belts used in movement of unloaded grain to the storage silos, grain left in the hold of the vessel used to transport the grain and losses during transhipping onto smaller vessels.

Table D.14.01 provides estimates of spillage of wheat grain and survival of *L. bonariensis* at different stages of the import pathway.

Contribution to model input parameters
Minimum and maximum estimates of losses during unloading of grain shipments are 0.2 and 0.6% respectively whilst estimates of losses during transport from port to processor are 0.06 and 0.1% respectively. No estimates of daily mortality rates of the pest in the commodity and waste are available but likely to be low.

Table D.14.01: Spillage of wheat grain and mortality of *L. bonariensis* after arrival at destination

Variable	Stage	Time between stages and spillage at stage
Consignment volume 100 kgs	Arrival	50-100 x100Kg[a]
Proportion of consignment units infested	Arrival	0-0.01%[b]
Time to unload	Airport /harbour	2-4 days[c]
Days commodity in storage at port	Airport /harbour	4-8 weeks[d]
Days in stage before loss	Airport /harbour	N/A (insect doesn't damage wheat seed)
Proportion commodity retained during stage	Airport /harbour	Min. 0.2%, max. 0.6%[e] 0.1-0.3% to 2-3%[f]
Daily pest mortality rate in commodity	Airport /harbour	?
Daily pest mortality rate in waste etc.	Airport /harbour	?
Time in transport from port	In transport from port	Min. 2, max. 5 days[g]
Days in stage before loss	In transport from port	N/A
Proportion commodity retained during stage	In transport from port	Min. 006%, Max. 0.1%[h]
Daily pest mortality rate in commodity	In transport from port	?
Daily pest mortality rate in waste etc.	In transport from port	?
Days commodity in stage	At wholesale/storage	?
Days in stage before loss	At wholesale/storage	N/A

[a] Source: Pers. Rec. Associated British Ports estimate of average wheat consignment from 3rd countries arriving at British ports.
[b] Estimated- no live insects intercepted in grain cargo arriving at EU ports to date.

[c,d] Pers. Rec. Associated British Ports estimate of average unloading time and days in port storage and delivery to receiver. But Schuttelaer, (2009) cites a mean and maximum storage times of 6 months to several years at silos at Rotterdam port.

[e] Average losses during storage at port and transit to receiver. Estimates from European Flour Mills, Italmopa, 2010, NAEGA, 2006.

[f] Tamis et al (2009) figures for losses during transhipment and transport of rape seed from port to processor. The higher estimates relate to the feed industry.

[g] Estimated road/rail shipment time from port to receiver

[h] Estimated spillage during transport from port to receiver. Italmopa, 2010

D.15 Interceptions in the EU

L. bonariensis was detected in shipments to the EU in 2010 as dead adult specimens in a grass seed mixture from three different geographical sources. The grass mix included *Lolium perenne* from New Zealand. Also in 2010 a large number of dead adult specimens was detected in a consignment of *Trifolium repens* from New Zealand followed in 2011 by a further 8 interceptions of *L. bonariensis*, in *L. perenne* and other seed, again from New Zealand (Ostojá-Starzewski, 2011).

D.16 Phenology of wheat

The development of wheat is determined by temperature and day length, with the life cycle in different agroclimatic zones being determined by the choice of variety (early, medium and late ripening cultivars) and sowing date. The sowing date of winter wheat differs in different climatic zones of Europe from around September in northern Europe, October in central Europe and between November and December in southern Europe. Key stages in the life cycle of wheat are crop emergence, the beginning of stem extension and flowering, which are competed in a Foundation Phase of six months, followed by a Construction Phase of two months and finally a Production Phase, also lasting two months (HGCA, 2008). The length of all phases is affected by temperature expressed as cumulative degree days above 0°C (DD0°C). A period of cool temperatures of between 0 and 12°C (vernalisation) reduces the duration of the Foundation Phase and the duration of all phases is reduced by warmer temperatures. The duration of the Foundation and Construction Phases is also affected by day length, with long days speeding up floral development in most varieties.

The Foundation Phase encompasses sowing, germination at around 150 DD>0°C, leaf emergence on the main shoot (requiring around 122 DD>0°C per leaf), root development and formation of tillers. Completion of this phase requires a total period of around six months and ~1,200DD>0°C from sowing. Stem elongation and storage continue throughout the following two month Construction Phase and in this period ear formation also begins. A thermal time of 2,100 DD>0°C from sowing is required to complete the phase. In the Production Phase, the final phase of the life cycle of wheat, flowering begins, followed by grain filling and ripening. The duration of all three phases requires a total of around 3,100>0°C from sowing in October of the previous year to harvesting around July/August. In southern Europe the life cycle is shortened and harvesting takes place as early as April/May.

Trnka et al (2014a, b) provide data on key phenological stages in the growth of European wheat for 14 locations from northern to southern Europe showing a progressively later sowing date, a tendency to earlier anthesis and earlier maturity moving from north to south. Table A4.16.01 shows the sowing and harvest periods of winter wheat at the same or closely located meteorology stations as used by Trnka et al (2014a, b) in north, central and southern Europe. Table 9 also shows degree days above the threshold of 10°C (DD>10°C) at these sites (BizEE 2015), above which development of *L. bonariensis* is possible. This shows a progressively increasing annual total DD>10°C from 727DD>10°C in Finland to 3,228 DD>10°C at Seville in southern Spain for 2014. *L. bonariensis* requires between 360 DD>10°C (Ferguson *et al*. 1996) and 454 DD>10.2°C (Barker, 1988) to complete its life cycle on perennial ryegrass (*Lolium perenne*) in New Zealand, implying that establishment may be possible in the central and southern states of Europe.

Table D.16.01: Sowing dates (blue cells), harvest dates (green cells) and monthly Degree Days above 10°C (DD .10°C) for sites in northern, central and southern Europe. Sources: Adapted from Trnka et al (2014b, supplementary table 3). Degree Days from BizEE, 2015

Locality				Degree days (DD) per month 2014												
Site	Country	Latitude	Longitude	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total DD
Jyväskylä	Finland	62.4N	25.68E	0	12	87	99	290	179	58	2	0	0	0	0	727
Uppsala	Sweden	59.90N	17.6E	3	22	78	112	292	204	85	25	3	0	0	0	824
Tylstrup	Denmark	57.19N	9.95E	4	35	77	152	287	181	128	67	9	0	0	0	940
Warsaw	Poland	52.22N	21.02E	28	99	191	239	399	310	190	84	13	1	0	0	1,554
Amsterdam	Netherlands	52.30N	4.77E	28	75	121	181	300	199	197	111	16	5	2	0	1,235
London	UK	51.48N	0.46W	36	68	122	216	309	204	201	125	29	11	6	0	1,327
Mannheim	Germany	49.46N	8.55E	53	132	165	287	350	254	210	128	14	2	5	0	1,600
Vienna	Austria	48.11N	16.57E	50	94	153	276	355	276	181	181	101	25	5	0	1,697
Debrecen	Hungary	47.49N	21.6E	57	111	198	310	376	334	226	102	28	0	0	2	1,744
Clermont-Ferrand	France	45.79N	3.15E	51	87	134	285	288	252	211	160	50	6	12	4	1,540
Montagnano	Italy	43.46N	11.85E	58	107	193	332	366	367	254	193	69	16	5	6	1,966
Madrid	Spain	40.44N	3.59W	86	182	244	361	449	474	335	240	59	31	36	16	2,513
Athens	Greece	37.94N	23.94E	93	156	297	426	515	535	384	250	132	86	49	43	2,966
Seville	Spain	37.42N	5.89W	140	251	370	416	479	510	397	343	167	48	50	57	3,228

D.17 Processing mills

Within the EU, business activities are classified according to the Nomenclature of Economic Activities code (in French, named *Nomenclature statistique des activités économiques dans la Communauté européenne* – leading to the codes commonly being referred to as NACE codes). The EU NACE codes align with the UN International Standard Industrial Classification (ISIC) system. Like CN import codes, NACE and ISIC codes have a hierarchical, top-down structure that begins with general characteristics and narrows down to the specifics. The first two digits of the code represent the major industry sector to which a business belongs. The third and fourth digits describe the sub-classification of the business group and specialization, respectively. Statistics produced on the basis of NACE are comparable at European level and, in general, at world level (Eurostat European Commission, 2008).

The codes used to describe business activities are listed in the most recent version of the NACE codes in Eurostat European Commission (2008). The NACE code used to identify businesses involved in the manufacturing of grain mill products, including wheat flour mills is C10.6.1. Note however that this code also includes other types of milling and grain processing (section D.25).

The numbers of manufacture of all grain mill products in each MS is shown in Table D.17.01.

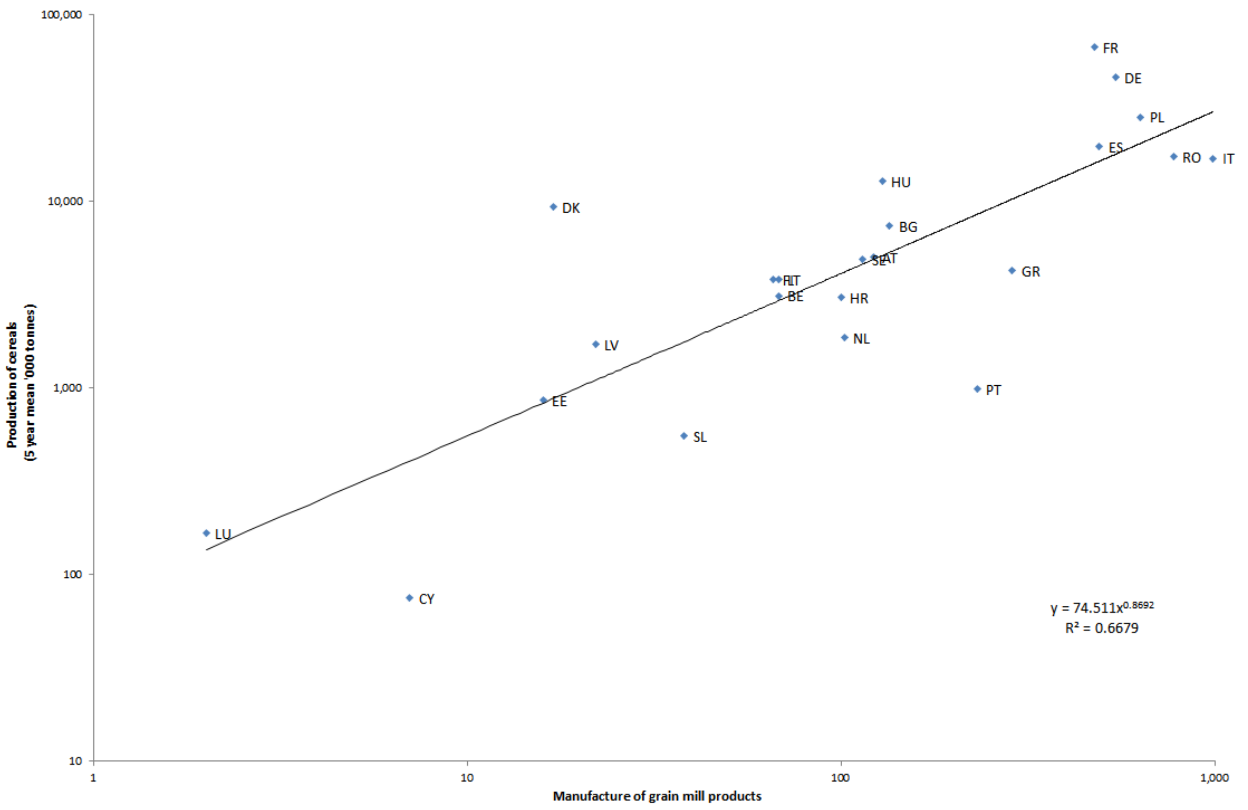
Table D.17.01: Number of business enterprises recorded as "Manufacturers of grain mill products" Source: Eurostat NACE_R2 Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]

EU total	5,744			
Italy	992		Belgium	68
Romania	776		Lithuania	68
Poland	632		Finland	66
Germany	544		Slovenia	38
Spain	490		Latvia	22
France	477		Denmark	17
Greece	287		Estonia	16
Portugal	232		Cyprus	7
Bulgaria	135		Luxembourg	2
Hungary	129		Czech Republic	no data *
Austria	122		Ireland	Confidential *
Sweden	114		Malta	Confidential *
Netherlands	102		Slovakia	Confidential *
Croatia	100		United Kingdom	Confidential *

*See Table D.17.02

For EU Member States where data are given, the sum of enterprises is 5,436. The total for the EU (28) is given as 5,744 suggesting that 308 mills are distributed across CZ, MT, SL, UK and IE.

To estimate the number of manufacturers of grain mill products in the five EU MS where no data were provided by EuroStat (Czech Republic, Ireland, Malta, Slovakia & United Kingdom) the relationship between mean annual cereal production and number of manufactures of grain mill products for the 23 other EU MS was examined (Figure D.17.01).



Note Log scales

Source: Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]

Figure D.17.01: Number of manufacturers of grain mill products vs production of cereals (5 year mean)

Assuming that the relationship indicated in Figure D.17.01 (r^2 = 0.6679) holds for the Czech Republic, Ireland, Malta, Slovakia & United Kingdom, then we can use this to estimate the number of manufacturers of grain mill products in these countries, and apportion the estimates so as to sum to 308 (the number required in order that the sum of EU MS business enterprises recorded as Manufacturers of grain mill products equals 5,436 across the EU 28) (Table D.17.02). This then provides the data to complete (Table D.17.021).

Table D.17.02: Estimated number of manufacturers of grain mill products for 5 EU MS where EuroStat data were not available

EU MS	Mean cereal production 2009-2013 ('000 tonnes)	Estimated number of manufacturers of grain mill products	Manufacturers apportioned in same ratio to sum to 308
Czech Republic	7,421	115	68
Ireland	2,228	34	20
Malta	0	0	0
Slovakia	3,209	50	30
United Kingdom	20,717	320	190
		sum 519	308

Although the number of manufacturers of grain mill products is 5,436 across the EU 28, the European Flour Mill Association suggests there are approximately 3,800 milling companies.[19]

An alternative method of determining the distribution of wheat processing sites across the EU was also explored by reviewing information provided by the European Flour Millers Association (www.flourmillers.eu), trade directories (https://companylist.org, http://www.europages.co.uk) and direct contact with MS government statistical services. Such data collection is limited to finding larger companies listed in trade directories and registered with trade organisations and the numbers are consequently lower than those reported by Eurostat.

Figure D.17.02 plots the larger flour mills in each Member State located in the NUTS regions of each country together with the main grain handling ports. Information on EU grain handling ports was obtained from the Eurostat database (Eurostat/database by themes/maritime transport/goods/quarterly data –main ports).

[19] http://www.flourmillers.eu/page/facts-figures-flour-milling-industry/

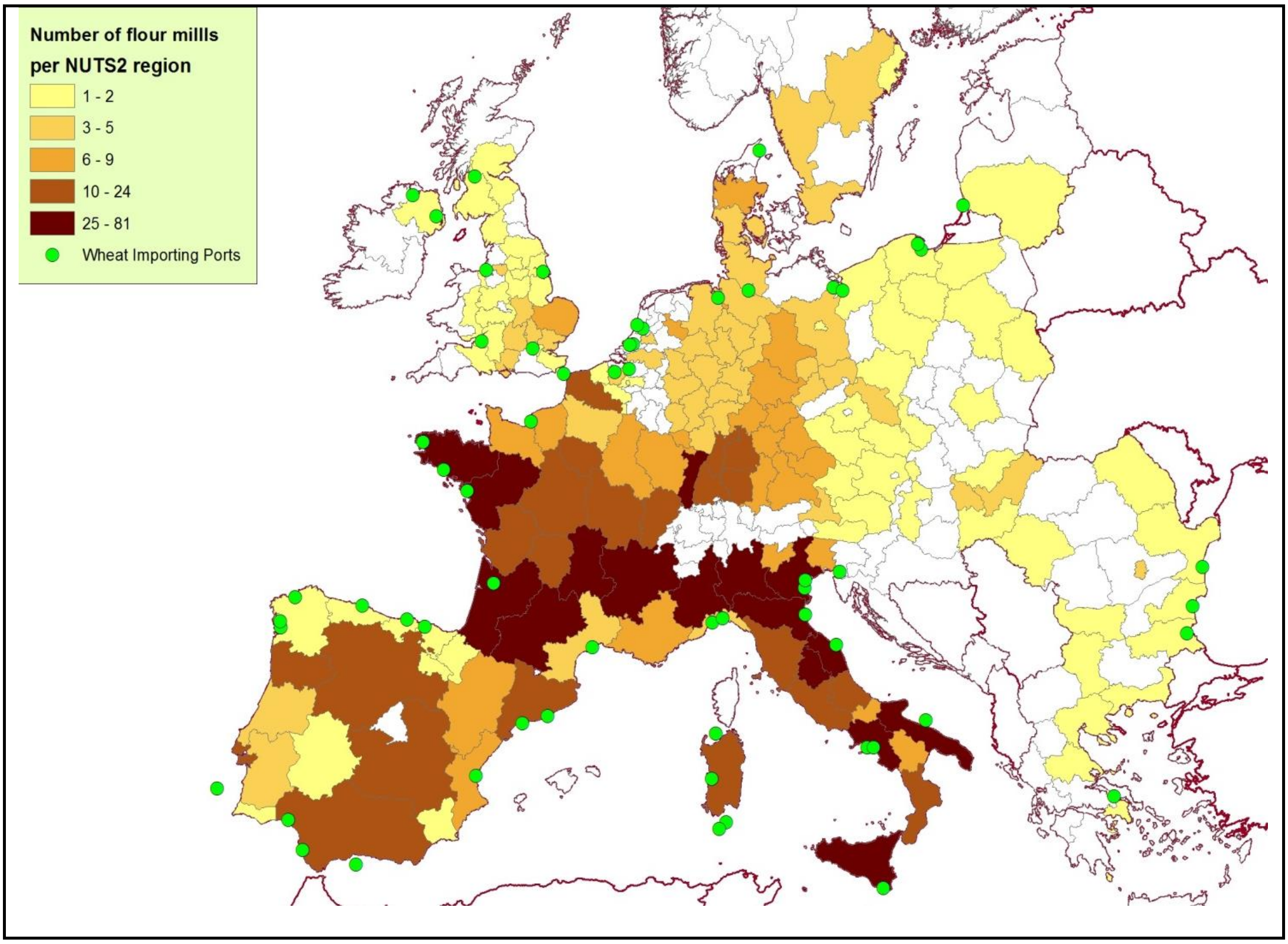


Figure D.17.02: Location of major flour mills and grain handling ports in EU MS

D.18 Uses for wheat

Total EU supply of wheat from 2010 to 2014 (Table D.18.01) has remained relatively constant at around 154 million tonnes with average import levels of around 5 million tonnes (3.34%). Of this supply approximately equal amounts were used for human consumption (36.3%) and animal feed (31.6%) with the remainder used for seed (3.4%) and feedstock for industrial purposes (6.8%). Use of wheat for bioethanol production accounted for around 41% of the total industrial usage.

Table D.18.01: Total supply and usage of wheat in the EU 2010-2014 ('000 mt) Source: EU Cereals Supply and Demand, European Commission, Directorate General for Agriculture and Rural development, Unit C5

Supply	2010/11	%	2011/12	%	2012/13	%	2013/14	%	Mean	Mean %
Beginning stocks	16,115		10,334		11,364		9,385		11,800	
Usable production	135,065		137,737		132,127		143,054		136,996	
Imports from third countries	4,497		7,123		5,250		3,724		5,149	3.34
Total	155,677	100.00	155,194	100.00	148,741	100	156,163	100	153,944	100
Domestic uses										
Human consumption	55,647	35.75	55,881	36.01	55,947	37.61	55,949	35.83	55,856	36.28
Animal feed	51,100	32.82	55,400	35.70	45,200	30.39	43,000	27.54	48,675	31.62
Industrial*	10,200	6.55	10,700	6.89	10,400	6.99	10,600	6.79	10,475	6.80
Seed	5,255	3.38	5,171	3.33	5,171	3.48	5,171	3.31	5,192	3.37
Losses	950	0.61	950	0.61	950	0.64	950	0.61	950	0.62
Exports to third countries	22,191	14.25	15,728	10.13	21,688	14.58	31,084	19.90	22,673	14.73
Final stocks	10,334	6.64	11,364	7.32	9,385	6.31	9,409	6.03	10,123	6.58

*Includes production of bioethanol and other products at an average of circa 4.35 million Mt 2010-2014.

D.19 Processing activities

Grain is shipped to wholesalers or directly to the processors where it is milled for food or animal feed or used for production of industrial products (starch, ethanol etc.) and a range of food additives.

The major factors which determine whether wheat can be used for flour production are variety and quality. The variety and quality are checked before shipment, but the latter can deteriorate under sub-optimal storage conditions during shipping. If fungal growth is detected, or germination has occurred, the wheat is no longer suitable for flour production and must then be used for animal feed or for fermentation into alcohol by the brewing industry or bioethanol in an industrial process to produce fuel.

Before unloading at the docks samples are taken to check for quality, uniformity and freedom from spoilage organism and quarantine pests and diseases. –X-rays are sometimes used to detect insect infestation. The wheat sample is then milled and baked to determine the end-use quality and identify the optimal handling procedures and storage conditions. The wheat batch is then stored in silos within controlled temperature, moisture and ventilation ranges to prevent sprouting and spoilage by growth of fungi.

Production of flour involves the following steps:

Cleaning

Involves a number of procedures to remove foreign material. These include passage of the grain through:

- magnetic separators to remove metallic objects
- vibrating screens to remove debris which is either too big or small to be wheat
- aspirators to remove dust and lighter impurities
- de-stoners to remove stones and grit of equivalent size to wheat seeds
- separators to eliminate anything else that is not the same size or shape as wheat seed
- scourers to remove outer husks and dirt

These processes together will likely remove any insect pests not detected at inspection.

Biological waste from the control and cleaning procedures is diverted for the production of animal feed with the remainder going to landfill.

Conditioning

Involves addition of precise amounts of moisture to aid separation of the constituents of the kernel followed by centrifugation to break up unsound kernals and eliminate them from the milling process.

The conditioned wheat is stored in bins for periods between 8 and 24 hours depending on the type of wheat (soft, medium or hard) and, if necessary, blended with other varieties to produce a specific type and quality of flour. At this point, high quality imported wheat may be added to produce flour of a premium quality.

Grinding and sifting

Reduction of the wheat kernels by passage through corrugated caste iron rollers to produce coarse particles of endosperm (middlings) which are graded and separated from the bran by sieves before returning to appropriate rollers to further reduce the grain, and remove the bran, until the appropriate flour is obtained.

This procedure is repeated using up to five more cycles of grinding and sifting, using grinders with successively finer corrugations and a series of up to 27 sifters, with progressively finer mesh, to reduce the wheat particles to granular middlings that are as free from bran as possible. Up to six different particle sizes may be produced by a single sifter with the larger particles removed from the top to return to the rollers and the finest collected at the bottom.

Reduction rolling

Reduction of germ particles by passage through a series of smooth reduction rolls to reduce the purified, granular middlings, or farina, to flour. Around 75% of the wheat grain is converted to flour by these processes with the remainder comprising shorts, bran and germ being classified as millfeed.

Biological waste from the control and cleaning procedures is diverted for the production of animal feed with the remainder going to landfill.

Reconstituting (gristing)

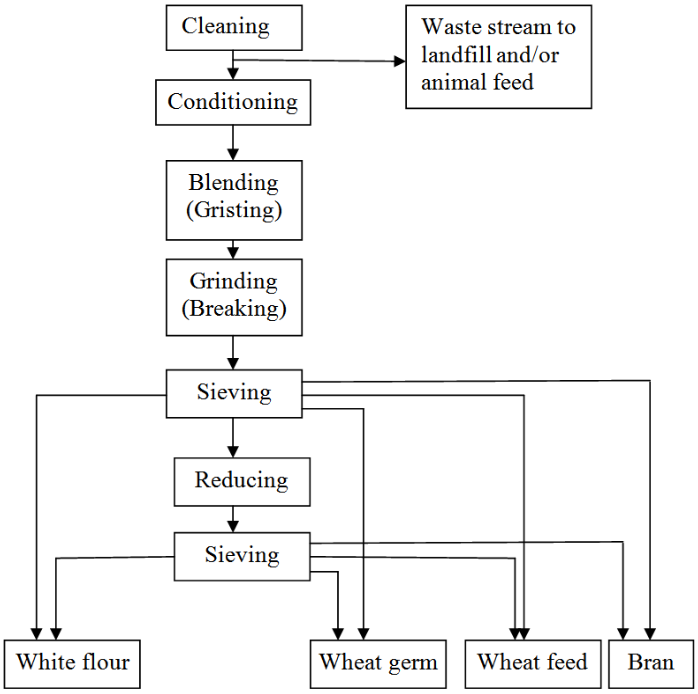
To produce wholegrain flour the bran and other parts of the grain removed during the milling process are re-blended with the flour in specific proportions. This process produces higher quality whole wheat flour than is achieved by grinding the whole wheat grain.

Bleaching

Towards the end of the milling process measured amounts of bleaching/maturing agent (usually chlorine or benzoyl peroxide) are added to the flour which duplicates and speeds up the natural oxidation process, whitens the flour and improves its baking qualities, without leaving harmful residues or destroying nutrients.

Before packing the flour is enriched by adding measured amounts of the three B vitamins (thiamin, niacin and riboflavin) as well as iron.

A simplified depiction of the above procedures is given in the flow diagram (Figure D.19.01) below.



Source: http://www.nabim.org.uk/flour-and-milling/the-milling-process/ (adaptation)

Figure D.19.01: Steps carried out in conversion of wheat grain to flour

D.20 Feed production

Wheat contributes almost 50 of the 500 million tonnes of feed that is required to support Europe's livestock production. Two thirds of this amount is produced on farm and the other third supplied by feed manufacturers. The most important factor in production of wheat for animal feed is high yield. The feed chain is the first link in the human food chain, which includes businesses that import raw materials from around the world, manufacturers of compound feeds and feed additives, wholesalers and transporters.

As with flour production, the grain is checked for quality, uniformity and freedom from spoilage organisms and quarantine pests before cleaning to remove foreign material. The need to remove other contaminating grain is less important in feed production than in the production of flour.

Raw material intake and cleaning are essentially the same procedures as those used in flour production. Wheat grain is received and stored, mixed with other grain and crushed, pressed into pellets and steamed. The pellets are then dried, cooled and stored for distribution. Products are distributed to farmers in trucks and no packaging is applied. No wastewater is generated during the production process and solid waste is composed mainly of foreign matter (metal, stones etc.) which is removed during the initial cleaning procedures.

The remaining production processes include the following procedures (Figure D.20.01).

Batching

A process of combining all the constituents in fixed proportions according to a feed formula which differs for different livestock and ensures that a better quality feed, with balanced nutrients, is produced.

Grinding

Grinding is a process of reducing solid ingredients to a required size in the same way that grain for flour production is treated. This increases the surface area exposed to heat and moisture which facilitates gelatinisation required for effective conditioning.

Mixing

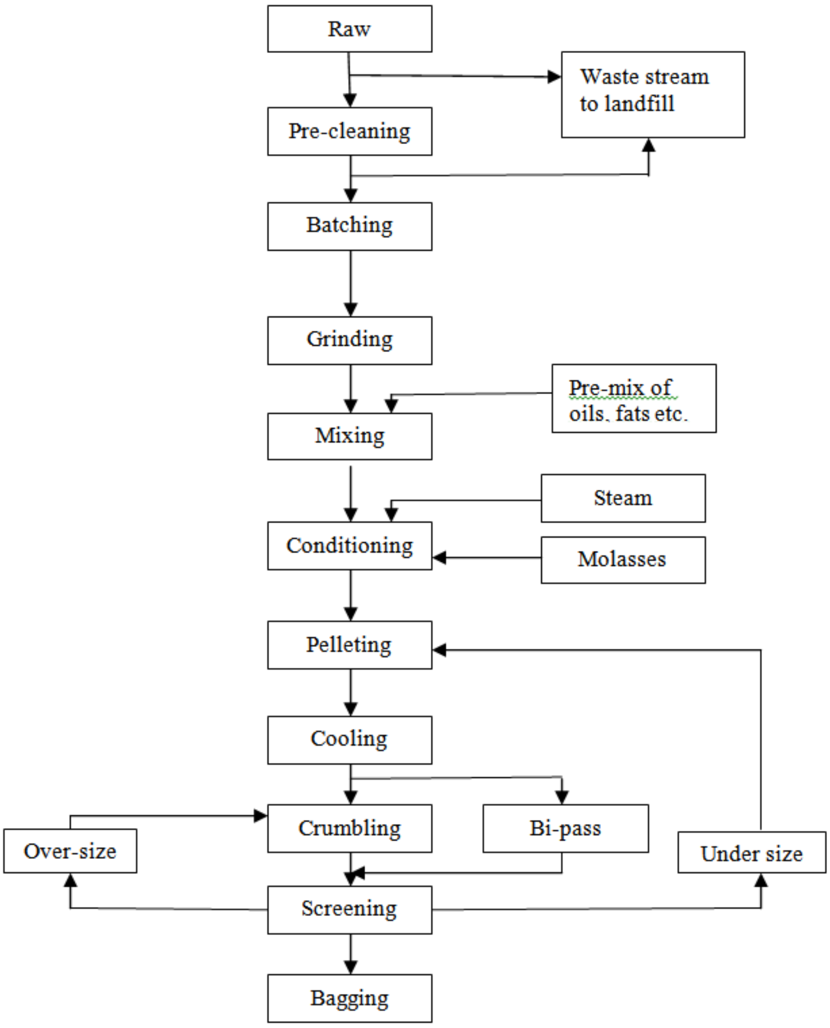
Mixing is the process of combining\blending of micro nutrients to produce a well-balanced feed.

Conditioning

Conditioning is a process of exposing milled grain to heat and moisture to achieve gelatinization and render the product more pliable for pelleting. The mixed feed is then roasted to increase its digestibility quality. The conditioned grain is pelleted, cooled and screened to remove under and oversized particles followed by bagging prior to shipment to wholesalers.

Bran and other waste products from the flour milling process are diverted to production of animal feed as are waste products produced by the drinks and biofuel industries. The quality standards and safety of animal feed in Europe are regulated by the European Feed Manufacturers' Federation (FEFAC) whose company members operate about 4,000 feed mills across the EU according to the manufacturing standards outlined in FEFAC's European Compound Feed and Premix Manufacturing Code, the EFMC.

The Biofuel producers compete for the same raw materials used in feed. Some of the by-products and waste from this process is rich in protein and can be used for production of animal feed.



Source: Adapted from 2010 Spectec Techno Projects Pvt. Ltd

Figure D.20.01: Steps carried out in conversion of wheat grain to animal feed

D.21 Industrial production

Around 6 million tonnes of wheat is used annually as a feedstock for industrial usages other than biofuel production. Products including starch, sugars and gluten are produced for the food industry, ethanol for the drinks industry, chemicals for the pharmaceutical industry and plastics, adhesives and paper for general usage. Waste products from these processes are used for animal feed or disposed of in landfill. Locations of refineries are shown in Figure D.21.01.

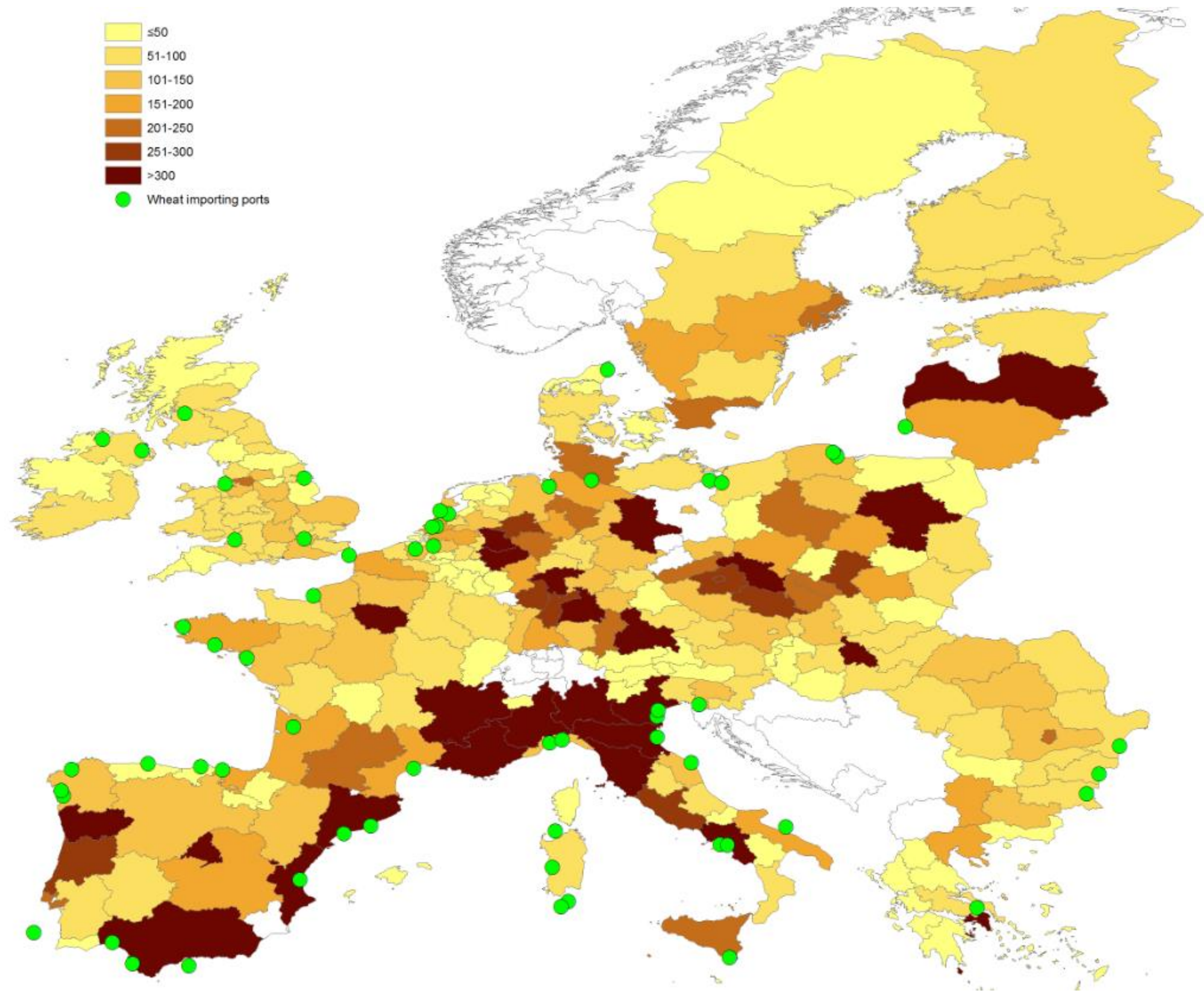


Figure D.21.01: Manufacturing sites of organic based chemicals NACEr2 classification 20.14 (includes bio-refineries) by NUTS2

D.22 Dispersal distance for *Listronotus*

In the introduction to a paper on *Listronotus* flight by Goldson *et al* (1999) the authors note that reports studying the flight of the weevil in New Zealand have been contradictory. Some studies say that flight is limited and most adults don't fly but walk. Others report that the weevil only flies due to overcrowding or poor host condition. Others disagree and suggest flight is linked with warm weather fronts. For example, Barker *et al.* (1989) dissected adults and found only a small proportion developed flight muscles. Within a population there was partition between adults that developed flight capability and those that developed mature reproductive organs. The proportion with flight capability within a population increased during periods of crowding or under laboratory conditions, when raised on an unfavorable host. When crowding was alleviated, there was degeneration of flight muscles and resumption of reproductive activity. However, another earlier study in New Zealand during the 1970s found that a large proportion of flying adults were gravid indicating that the energy partitioning, often observed in insect species where reproduction and flight are mutually exclusive, did not occur in *L. bonariensis* (Goldson, 1981).

Regarding model inputs, we assume that a proportion of adults can fly although most will disperse by walking (assume 500m) but that some adults can fly (max = 5km) which seems reasonable based on what is written in NZ literature, and general knowledge about small weevils. Considering the literature that suggests flight is a response to overcrowding and poor host, we doubt that overcrowding will be a problem on the pathway at this point so would NOT expect flight muscles to develop; instead adults focus on reproduction. This would be a sensible strategy for a new population. Nevertheless, a precautionary approach would be to use a triangular distribution with 5km as the upper estimate.

Threshold for flight Pottinger (1966) gave a threshold temp of 15C with wind speed < 13 km/h and RH <60% but Goldson et al., (1999) gave threshold as 19C, windspeed < 10.8km/h, rel hum < 81%. Goldson reported temp as most important threshold.

D.23 Import data (wheat)

Table D.23.01: Importation of spelt, common wheat and meslin (excl. seed) (x100kg) into EU MS from producer countries in which *L. bonariensis* is endemic for years 2005-2011 (No imports from these countries recorded for 2012 to 2014)

PARTNER	**ARGENTINA (x 100Kg)**							**AUSTRALIA (x 100Kg)**						
Reporter/period	2005	2006	2007	2008	2009	2010	2011	2005	2006	2007	2008	2009	2010	2011
Austria	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Belgium (and Luxbg)	:	243	1,935	10,699	1,742	250	:	:	:	:	:	:	:	:
Bulgaria	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Croatia	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Cyprus	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Czech republic	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Denmark	:	:	:	:	:	:	:	:	:	:	:	:	:	
Estonia	:	:	:	:	:	:	:	:	:	:	:	:	:	:
France	:	:	:	9,787	3,074	17	9,589	:	:	:	:	:	:	1
Germany (incl. DD from 1991)	:	:	:	6,217	:	2	1,007	:	:	:	:		:	:
Greece	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Hungary	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Ireland	:	:	:	:	:	:	:	:	:	:	2,002	:	:	:
Italy	:	:	:	:	515	:	300,469	803,402	1,160,873	:	:	1,706,485	573,987	:
Latvia	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Lithuania	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Luxembourg	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Malta	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Netherlands	:	:	:	13,655	:	:	11,936	:	:	:	:	:	:	:
Poland	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Portugal	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Romania	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Slovakia	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Slovenia	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Spain	853,989	:	:	494	482	:	1,473	471,089	:	:	:	1,035,644	111,221	:
Sweden	:	:	:	:	:	:	:	:	:	:	:	:	:	:
United kingdom	:	34,422	81,047	49,536	14,607	:	24,235	188,377	113,292	913	87,929	747,893	18,465	5,390
EU27	853,989	34,665	82,982	90,388	20,420	269	348,709	1,462,868	1,274,165	913	89,931	3,490,022	703,673	5,391

PARTNER	**BRAZIL (x 100Kg)**								**NZ (x 100Kg)**							
Reporter/period	2005	2006	2007	2008	2009	2010	2011	2012	2005	2006	2007	2008	2009	2010	2011	2012
Austria	:	:	:	:	:	:	:	:		8,562	:	:	:	:	:	:
Belgium (and Luxbg -> 1998)	:	:	:	1,404	:	:	:	:	:	:	:	:	:	:	:	:
Bulgaria	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Croatia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Cyprus	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Czech republic (cs->1992)	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Denmark	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Estonia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
France	:	:	1,288	:	250	:		:	:	:	:	:	:	:	:	:
Germany (incl. DD from 1991)	:	:	:	:		:		:	:	:	:	16	:		:	:
Greece	:	29,999	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Hungary	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Ireland	:	10	:	:	48	:	5	:	:	:	:	:	:	:	:	:
Italy	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Latvia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Lithuania	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Luxembourg	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Malta	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Netherlands	:	:	:	:	2,059			:	3,011	4,333	4,752	1,489	:	:	2,150	:
Poland	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Portugal	:	:	21	3	1	:	:	:	:	:	:	:	:	:	:	:
Romania	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Slovakia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Slovenia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Spain	:	2,884,350	:	:	:	:	116,973	:	:	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
United kingdom	:	:	:	:	:	:	:	:	:	:	4	2	1	2	:	:
EU27	:	2,914,359	1,309	1,407	2,358		116,978	:	3,011	12,895	4,756	1,507	1	2	2,150	:

PARTNER	**URUGUAY**							
Reporter/period	2005	2006	2007	2008	2009	2010	2011	2012
Austria	:	:	:	:	:	:	:	:
BELGIUM (and LUXBG -> 1998)	:	:	:	:	:	:	:	:

Bulgaria	:	:	:	:	:	:	:	:
Croatia	:	:	:	:	:	:	:	:
Cyprus	:	:	:	:	:	:	:	:
Czech republic (cs->1992)	:	:	:	:	:	:	:	:
Denmark	:	:	:	:	:	:	:	:
Estonia	:	:	:	:	:	:	:	:
France	:	:	:	4,808	:	:	:	:
GERMANY (incl DD from 1991)	:	:	:	9,157	:	:	:	:
Greece	:	:	:	:	:	:	:	:
Hungary	:	:	:	:	:	:	:	:
Ireland	:	:	:	:	:	:	:	:
Italy	:	:	:	:	:	:	:	:
Latvia	:	:	:	:	:	:	:	:
Lithuania	:	:	:	:	:	:	:	:
Luxembourg	:	:	:	:	:	:	:	:
Malta	:	:	:	:	:	:	:	:
Netherlands	:	:	:	3,053	:	:	:	:
Poland	:	:	:	:	:	:	:	:
Portugal	:	:	:	:	:	:	:	:
Romania	:	:	:	:	:	:	:	:
Slovakia	:	:	:	:	:	:	:	:
Slovenia	:	:	:	:	:	:	:	:
Spain	:	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	:	:
United kingdom	:	:	9,878	5,031	:	:	:	:
EU27	:	:	9,878	22,049	:	:	:	:

D.24 Major EU dry bulk ports – agricultural import data

Table D.24.01: Main EU entry ports for landing of dry bulk agricultural products from target countries and quantities landed 2010-2013

EU MS	Origin	Port of entry	Quantity Dry bulk - Agricultural products (1000 tonnes/quarter)															
			YEAR/QUARTER															
			2010				2011				2012				2013			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Belgium	Argentina	Antwerp						24			135							
		Ghent		41				42	53		164							13
	Australia	Antwerp							19	30								
		Ghent	:	119	:	:	61	111	:	46	293	455	107	:	399	486	:	61
	Brazil	Antwerp	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Ghent	:	27	:	:	44	28	66	:	:	:	48	:	:	:	:	:
	Uruguay	Antwerp																
		Ghent																
		TOTAL	0	187	0	0	105	205	138	76	592	455	155	0	399	486	0	74
Bulgaria																		
	Brazil	Varna	24	25	18	:	:	:	17	:	:	:	:	:	:	:	:	:
		Burgas	:	:	48	:	26	:	38	27	:	:	:	:	:	30	:	:

		TOTAL	24	25	66	0	26	0	55	27	0	0	0	0	0	30	0	0
Croatia	Argentina	Ploce	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Split	:	:	:	:	:	:	:	:	5	8	:	:	:	:	:	:
	Brazil	Ploce	:	:	:	:	:	:	:	:	28	:	:	:	:	:	:	29
		Split	:	37	7	:	:	8	:	:	:	:	:	:	:	:	:	:
		TOTAL	0	37	7	0	0	0	8	0	33	8	0	0	0	0	0	29
Cyprus	Argentina	Larnaka	15	5	14	9	6	:	:	8	3	:	16	:	4	:	4	:
		Lemesos	:	:	:	:	:	:	7	7	7	:	9	:	:	:	:	:
		Larnaka	:	:	:	:	:	:	:	:	8	:	:	:	:	:	:	:
		Lemesos	:	:	:	:	:	:	:	9	:	8	:	:	:	:	:	:
		TOTAL	15	5	14	9	6	0	7	24	18	8	25	0	4	0	4	0
Denmark	Argentina	Fredericia (Og Shell-Havnen)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Brazil	Fredericia (Og Shell-Havnen)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Estonia	Argentina	Tallin	:	:	:	:	:	:	:	11	:	24	11	:	:	:	:	:
	Uruguay	Tallin	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		TOTAL	0	0	0	0	0	0	0	11	0	24	11	0	0	0	0	0
France	Argentina	Bordeaux	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Brest	:	66	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Le Havre	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Lorient	16	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Nantes St Nazaire	36	26	:	100	32	41	:	96	31	39	:	92	:	:	:	:
		Sete	:	:	:	27	38	24	:	:	39	25	:	:	:	:	:	:
		Mediteranean and Monaco	:	:	:	27	38	24	:	:	39	25	:	:	:	:	:	:
		Atlantic and N. Sea	52	93	:	100	32	41	:	96	31	39	:	92	:	:	:	:
	Brazil	Brest	27	53	41	24	:	:	:	:	:	:	:	:	:	:	:	:
		Le Havre	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

		Lorient	125	133	191	203	136	96	:	:	109	78	:	:	:	:	:	:
		Mediteranean and Monaco	40	61	47	48	20	27	52	55	20	28	53	56	:	:	:	:
		Atlantic and N. Sea	392	670	595	600	353	505	255	418	319	469	245	403	:	:	:	:
		TOTAL	688	1,102	874	1,129	649	758	307	665	588	703	298	643	0	0	0	0
Germany	Argentina	Baltic	:	:	:	:	:	:	:	:	23	:	14	:	:	:	:	:
		Brake	:	6	:	84	:	:	:	:	:	:	:	:	:	:	:	24
		Hamburg	:	:	:	:	:	:	:	63	159	110	46	46	:	56	:	:
		N. Sea	:	6	:	84	:	:	:	63	159	110	46	46	:	56	:	24
	Australia	Hamburg	:	:	:	:	122	170	36	:	55	241	:	:	61	87	:	:
		N. Sea	:	:	:	:	122	170	36	:	55	241	:	:	61	87	:	:
	Brazil	Brake	:	:	:	48	:	:	:	:	:	:	:	44	49	60	:	:
		Hamburg	47	339	119	:	116	297	194	31	100	318	199	131	15	296	206	48
		N. Sea	47	339	119	48	116	297	194	31	100	318	199	175	68	357	206	48

	Chile	N. Sea	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	Uruguay	Hamburg	:	94	323	180	:	278	280	122	:	:	81	:	:	120	234	:
		N. Sea	:	94	323	180	:	278	280	122	:	:	81	:	:	120	234	:
		TOTAL	94	866	884	456	232	1,150	948	306	200	636	560	350	132	953	880	96
Greece	Argentina	Chalkida	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	Brazil	Chalkida	29	15	9	:	:	15	:	:	:	:	:	:	:	:	:	:
		TOTAL	29	15	9	0	0	15	0	0	0	0	0	0	0	0	0	0
Ireland	Argentina	Cork	:	72	33	52	:	43	34	63	70	44	62	64	50	61	69	70
		Dublin	14	39	47	43	41	45	52	93	54	60	51	63	19	30	65	83
		Limerick	:	:	:	7	15	:	:	:	:	:	:	:	:	:	:	:
	Brazil	Cork	35	:	32	37	:	:	:	7	:	:	:	:	:	:	:	:
		Dublin	12	:	:	:	:	:	:	25	10	14	:	:	:	:	18	:
		Limerick	:	:	18	22	:	:	:	:	8	:	:	:	:	:	:	:
		TOTAL	61	111	130	161	56	88	86	188	142	118	113	127	69	91	152	153
Italy	Argentina	Ancona	23	27	23	13	:	:	:	:	:	:	:	:	:	:	:	:

		Chioggia	44	59	30	41	29	67	40	89	:	:	:	49	42	55	53	13
		Napoli	9	:	:	:	8	16	10	6	13	7	10	:	:	:	20	12
		Oristano	:	:	6	:	:	:	:	16	:	:	:	:	:	:	:	:
		Pozallio	11	13	10	10	5	6	5	16	:	6	6	8	:	4	5	6
		Ravenna	85	136	219	162	85	94	219	162	131	237	122	119	44	28	20	80
		Savona	22	48	68	90	53	150	69	35	101	107	33	:	:	:	:	26
		Venesia	67	187	297	303	124	86	197	89	61	130	64	25	36	221	161	94
	Australia	Bari	46	40	32	43	:	44	:	:	32	154	:	:	:	58	:	:
		Ravenna				17												
		Venesia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	Brazil	Ancona	25	77	:	:	:	:	:	:	:	:	:	12	:	:	:	:
		Bari	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Chioggia	:	:	:	:	:	:	:	5	:	:	:	:	:	60	141	:
		Oristano	:	:	:	:	18	:	:	:	:	:	:	:	:	:	:	:
		Ravenna	24	103	93	2	:	:	:	:	38	110	78	43	51	75	28	:

		Savona	:	13	:	:	:	:	:	:	:	:	27	63	18	:	85	19
		Trieste	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Venesia	27	109	:	13	:	:	84	:	:	41	43	:	:	46	131	27
	Columbia	Italy	3	7	:	1	1	2	3	3	:	:	:	:	:	:	:	:
		Salerno	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Other	3	7	:	1	1	2	3	3								
	Uruguay	Italy	26	:	14	:	:	:	64	:	:	:	:	:	26	44	60	:
		Venesia	26	:	12	:	:	:	64	:	:	:	:	:	:	44	60	:
		TOTAL	441	826	804	679	324	467	758	424	376	792	383	319	217	635	764	277
Latvia	Argentina	Liepaja	:	:	:	:	:	:	:	:	:	:	:	35	:	37	:	38
		Riga	:	:	:	50	31	23	33	33	26	66	:	30	:	24	54	80
	Brazil	Riga	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Ventspils	:	39	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Uruguay		Riga	:	:	:	:	:	:	30	:	:	:	:	:	:	:	:	:
		TOTAL	0	39	0	50	31	23	63	33	26	66	0	65	0	61	54	118

Lithuania	Argentina	Klaipeda	:	:	:	:	:	26	35	37	20	17	49	92	48	:	:	:
		TOTAL	0	0	0	0	0	26	35	37	20	17	49	92	48	0	0	0
Malta	Brazil	Valetta	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	Columbia	Valetta	:	:	:	:	:	:	:	4	:	2	:	2	2	:	:	3
		TOTAL	0	0	0	0	0	0	0	4	0	2	0	2	2	0	0	3
Netherlands	Argentina	Amsterdam	93	390	64	216	94	412	331	333	332	198	309	92	264	162	89	113
		Rotterdam	199	617	441	567	368	567	460	381	322	331	264	337	188	446	433	577
	Australia	Amsterdam	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Rotterdam	:	62	7	:	194	318	18	61	123	18	22	50	18	53	47	:
		Vlaardingen	:	:	:	:	:	:	:	:	23	7	:	29	6	:	6	20
	Brazil	Amsterdam	1,112	1,067	1,124	1,150	640	892	510	581	747	631	589	796	1,019	1,105	1,180	833
		Rotterdam	153	522	619	492	538	690	908	610	402	817	869	654	691	1,273	1,036	419
		Velsen	:	:	:	:	:	110	102	:	:	:	:	:	:	:	:	:
	Chile	Rotterdam	:	:	:	:	148	49	121	202	45	:	:	:	50	:	234	:
	New Zealand	Vlissingen	:	:	:	:	:	9	:	:	:	12	:	:	:	7	:	:

	Uruguay	Rotterdam	76	45	186	39	:	137	97	181	139	100	97	47	48	49	141	47
		TOTAL	1,633	2,703	2,441	2,464	1,982	3,184	2,547	2,349	2,133	2,114	2,150	2,005	2,284	3,095	3,166	2,009
Poland	Argentina	Gdansk	:	27	83	116	37	115	81	92	38	89	76	73	:	31	29	84
		Gdynia	71	169	173	99	232	127	209	215	193	113	118	150	78	75	148	206
		Swinoujscie	:	:	4	:	:	:	:	2	:	25	:	37	:	62	26	:
		Szczecin	:	13	57	40	65	29	:	26	:	25	:	:	:	:	10	13
		TOTAL	71	209	317	255	334	271	290	335	231	252	194	260	78	168	213	303
Portugal	Argentina	Leixões	:	12	14	32	15	16	17	:	:	:	:	:	:	:	:	:
		Lisbon	39	40	55	16	:	164	:	64	44	127	2	:	17	61	:	29
	Brazil	Leixões	:	:	27	:	:	19	20	16	31	16	17	:	:	:	16	:
		Lisbon	79	255	253	250	253	142	103	60	103	109	170	165	376	268	371	9
		Setubbal	:	:	:	:	:	:	26	:	:	:	:	:	:	:	:	:
		Leixões	:	:	:	26	:	:	:	:	:	:	:	:	:	:	:	:
		Lisbon	37	28	31	:	:	56	:	:	:	:	:	:	:	28	:	:
		TOTAL	155	335	380	324	268	397	166	140	178	252	189	165	393	357	387	38

Romania	Argentina	Constanta	37	46	47	47	100	21	23	:	:	17	21	25	27	69	47	105
	Brazil	Constanta	27	121	154	80	28	212	224	215	125	158	127	56	69	151	91	:
	Columbia	Constanta	:	:	1	:	:	:	:	:	:	:	:	:	:	:	:	:
	Uruguay	Constanta	:	:	:	:	25	:	:	:	:	:	:	:	:	:	:	:
		TOTAL	64	167	202	127	153	233	247	215	125	175	148	81	96	220	138	105
Slovenia	Argentina	Koper	:	6	2	28	:	13	:	:	9	16	2	:	:	7	:	41
	Brazil	Koper	110	194	176	138	80	253	129	189	106	170	152	89	75	157	143	104
	Columbia	Koper	:	:	:	:	:	:	1	:	:	:	:	:	:	:	:	2
	Uruguay	Koper	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		TOTAL	110	200	178	166	80	266	129	189	115	186	154	89	75	164	143	147
Spain	Argentina	Barcelona	:	147	77	:	11	130	109	42	:	:	:	59	50	165	141	:
		Cadiz	29	31	42	26	29	31	36	40	15	80	69	20	15	44	44	44
		Cartegena	20	98	28	114	32	60	69	122	94	100	138	:	:	45	:	40
		Genoa	15	12	20	18	:	:	:	:	:	:	:	:	:	:	:	:
		Guijon	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

		Huelva	39	65	48	215	33	76	92	48	76	99	79	23	:	68	88	118
		La Coruna	17	63	153	79	98	181	31	91	80	115	123	31	28	90	66	48
		Las Palmas	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Malaga	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Marin Pontevedra	17	20	19	40	33	61	47	34	20	49	34	20	16	20	:	26
		Santander	39	49	41	97	36	12	95	28	40	14	35	19	:	:	20	:
		Tarragona	52	158	97	189	105	97	166	72	170	157	167	24	79	67	102	130
		Valencia	:	43	17	25	:	27	26	31	:	26	:	:	21	:	:	29
		Villagarcia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		N. Atlantic	74	201	254	216	168	254	173	191	151	178	229	115	44	136	85	74
		S. Atlantic	140	543	309	571	209	422	497	355	354	462	453	160	165	389	375	362
	Australia	Cadiz	:	:	:	:	:	10	:	:	:	17	13	11	:	:	:	:
		Tarragona	11	:	:	:	:	30	:	:	22	16	19	:	:	:	:	:
		Valencia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	Brazil	Barcelona	140	232	364	280	177	304	327	181	315	354	321	90	132	215	257	226

		Bibao	20	141	178	41	50	297	89	186	265	256	155	25	60	266	205	20
		Cadiz	28	6	30	8	8	13	:	16	25	:	:	:	:	:	43	:
		Cartegena	92	209	292	222	75	414	73	169	252	221	140	115	148	237	282	112
		Guijon	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Huelva	16	36	69	97	10	124	82	101	26	:	52	48	:	26	48	:
		La Coruna	26	39	114	79	126	36	32	22	3	36	25	52	92	8	180	101
		Malaga	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Marin Pontevedra	:	16	62	24	31	8	:	7	4	8	6	1	104	20	67	25
		Santander	18	:	30	:	31	10	17	25	13	12	37	17	:	:	:	29
		Tarragona	28	56	106	159	75	38	18	6	205	:	34	103	208	11	51	:
		Valencia	:	:	41	10	:	7	26	:	:	:	:	:	40	11	:	:
		Villagarcia	:	:	:	25	21	:	:	:	:	:	:	34	:	:	:	:
		N. Atlantic	64	196	384	169	259	351	138	240	285	312	223	129	256	293	451	175
		S. Atlantic	304	539	902	777	345	900	530	471	825	575	546	357	529	501	681	338
	Uruguay	Bibao	:	11	:	:	:	:	:	:	:	:	:	:	:	:	:	:

		Cadiz	:	:	:	:	:	:	:	:	:	:	:	:	15	:	:	:
		Cartegena	:	:	:	53	:	:	:	:	:	:	:	:	32	:	:	:
		Guijon																
		Huelva	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		La Coruna	:	:	:	:	:	:	:	:	:	:	13	:	:	:	:	:
		Malaga	:	:	:	10	:	:	:	:	:	:	:	:	:	:	:	:
		Tarragona	:	:	:	43	:	:	:	:	:	:	:	:	45	:	:	:
		Valencia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		Villagarcia	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		N. Atlantic	:	11	:	26	:	:	:	:	:	:	28	26	43	:	:	:
		S. Atlantic	:	:	:	106	:	:	:	:	:	:	:	87	92	:	:	:
		TOTAL	1,189	2,922	3,677	3,719	1,926	3,893	2,673	2,478	3,240	3,087	2,939	1,566	2,214	2,612	3,186	1,897
UK	Argentina	Belfast	46	113	82	155	115	101	116	130	130	113	110	137	72	110	127	86
		Bristol	15	38	80	44	77	:	32	66	:	61	85	33	42	39	39	47
		Clydeport	15	19	6	29	:	:	:	28	36	17	:	18	:	16	16	28

		Immingham	24	22	25	59	:	70	102	58	42	28	:	:	:	14	14	:
		Liverpool	31	175	76	229	120	129	112	21	104	122	316	144	72	101	229	105
		London	:	:	:	:	:	:	46	:	:	35	:	24	:	:	:	38
		Londonderry	:	:	:	14	:	:	:	:	:	:	:	:	:	:	10	20
		Southampton	:	:	:	28	19	:	:	34	19	24	:	:	:	:	14	26
	Australia	London	:	:	:	:	:	:	:	:	:	10	:	:	:	:	8	:
	Brazil	Belfast	74	51	66	114	25	38	35	13	27	15	29	18	26	15	28	24
		Bristol	:	:	8	:	:	:	:	:	:	:	:	:	:	:	:	:
		Clydeport	11	26	16	12	19	65	:	24	27	:	25	:	14	:	:	:
		Immingham	:	25	38	62	59	65	54	:	58	:	115	:	30	30	:	:
		Liverpool	106	146	237	151	134	172	160	390	324	205	177	71	148	181	78	:
		London	96	108	188	135	72	:	106	63	38	27	86	57	27	:	54	:
		Londonderry	:	:	:	:	:	:	:	:	:	:	:	:	9	:	16	:
		Southampton	19	36	21	16	:	:	:	:	:	:	:	:	:	:	:	:
	Chile	Bristol	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

	NZ	UK	:	:	:	:	:	:	:	:	:	7	:	:	:	11	:	:
	Uruguay	UK	:	25	:	:	:	:	:	:	:	:	:	:	:	:	:	:
		TOTAL	437	784	843	1,0 48	640	640	763	827	805	664	943	502	440	517	633	374

D.25 NACE code for grain mills

Table D.25.01: NACE codes used to identify businesses involved in the processing and preserving of fruit and vegetables

Class	Division	Group	Class	Description
C				Manufacturing
	10			Manufacture of food products
		10.6		Manufacture of grain mill products, starches and starch products
			10.61	Manufacture of grain mill products: Almond grinding, Barley meal production, Barley milling, Bean grinding, Bean milling, Bean splitting, Blended flour (prepared) mfr, Bran production, Breakfast cereal (cooked) mfr, Breakfast cereal (uncooked) mfr, Cake mixture mfr, Cereal breakfast mfr, **Cereal grains**, **flour**, groats, meal or pellets mfr, Chicory root drying mfr, Corn or other cereal grains mfr, Cornflake mfr, Cornflour mfr, Dough for bread, cakes, biscuits or pancakes mfr, Flaked maize production, Flour and meal of edible nuts production, **Flour milling**, Flour mixes mfr, **Flour of cereal grains production**, Flour of dried leguminous vegetables production, Flour or meal of dried leguminous vegetables production, Flour production, Glazed rice mfr, Grain milling, Grist milling, Groats production, Lentil splitting grinding or milling, Maize flaked production, Maize flour and meal production, Meal from grain mfr, Oat flour and meal mfr, Oat grinding, rolling, crushing or flaking, Parboiled or converted rice (husked, milled, polished, glazed) production, Pea splitting, milling or grinding, Polished rice mfr, Production of flour groats meal or pellets from cereal grains, Pudding mixture mfr, Puffed rice mfr, Puffed wheat mfr, Rice cleaning, Rice flaking, Rice flour production, Rice husking, Rice milling, Rice rolling, Rye flour and meal mfr, Rye flour production of, Rye milling, Rye rolling, Sago grinding, Self raising and patent flour mfr, Soya bean grinding, Soya bean milling, Soya flour and meal mfr, Vegetable milling, Wheat flake mfr, Wheat meal flour production, **Wheat milling**, Wheat offal, Barley processing (blocked, flaked, puffed or pearled), Flour and meal of roots or tubers production, Meal of dried leguminous vegetables production, Rye flaking, Semolina milling, Wheat pellets flour production.

			10.62	Manufacture of starches and starch products

D.26 Commercial bio-refineries in Europe

Belgium
Location: Rodenhuizedok (Port of Ghent)
Company: Alco Bio Fuels
Feedstock: Wheat
Product: bio-ethanol (150,000-m⇡)
Start: 2008
Website: www.alcogroup.com

Belgium
Location: Wanze
Company: BioWanze (Südzucker)
Feedstock: Wheat (800,000 t/a)
Product: bio-ethanol (300,000-m^3/a), gluten, soluble protein concentrate (200,00t/a)
Start: 2009
Website: www.biowanze.be/fr/Start/

Belgium
Location: Aalst
Company: Syral (Tereos)
Feedstock: wheat (420,000 t/a)
Product: Starch derivatives 450,000t/a) concentrate (200,00t/a)
Start: 2008
Website: www.syral.com

Denmark
Dong Inbicon Biomass Refinery
Wheat straw collection
infrastructure available from co-location with heat and power generation

France
Location: Les Sohettes, Pomacle – Bazancourt (Champagne Ardenne)
Company: Cristanol 2,
Feedstock: wheat (350,000 t/a)
Product: Bioethanol (160 kt/a)
Start: 2009
Website: www.chamtor.fr

France
Location: Les Sohettes, Pomacle – Bazancourt (Champagne Ardenne)
Company: Chamtor
Feedstock: wheat (250,000 t/a)
Product: Starch & glucose (250,000 t/a)
Start: 2009
Website: www.chamtor.fr

France
Location: Les Sohettes, Pomacle – Bazancourt (Champagne Ardenne)
Company: ARD
Feedstock: wheat
Product: R&D
Start: 1989
Website: www.a-r-d.fr/

France
Location: Les Sohettes, Pomacle – Bazancourt (Champagne Ardenne)
Company: Soliance
Feedstock: wheat
Product: Cosmetic ingredients
Start: 2008
Website: www.soliance.com

France
Location: Lestrem
Company: Roquette
Feedstock: wheat (1,700,000t/a)
Product: Starch, food, feed, bulk and fine chemicals, succinic acid, ethanol…
Start:?
Website: www.roquette.fr

France
Location: Lestrem
Company: Bio-Hub prgm
Feedstock: wheat and maize
Product: Bioplastics
Start:2006
Website: www.biohub.fr

France

Bazancourt-Pomacle Biorefinery
Feedstock supply (wheat and glucose)

Netherlands
Location: Sas van Gent
Company: CARGILL
Feedstock: wheat and corn
Product: Starches, starch derivates, wheat proteins, and glucose
Start: 2006
Website: www.cargill.com

Netherlands
Location: Sas van Gent
Company: Royal Nedalco
Feedstock: wheat and corn
Product: Bioethanol (2.2 Ml/a), DDGS
Start:2005
Website: www.nedalco.com

UK
Location: Trafford Park, Manchester
Company: CARGILL
Feedstock: wheat (750,000t/a)
ProductStarches, starch derivates, wheat proteins, and glucose, (2) Bioethanol (2.2 Ml/a), DDGS
Start: 2006
Website: www.cargill.com

UK
Location: Trafford Park, Manchester
Company: Royal Nedalco
Feedstock: wheat (750,000t/a) shared with CARGILL
Product: Bioethanol (2.2 Ml/a), DDGS
Start: 2006
Website: www.nedalco.com

D.27 NACE codes

Table D.27.01: NACE code used to estimate location of bio-refineries and industrial processing of wheat grain for alcohol

Class	Division	Group	Class	Description
C				Manufacturing
	20			Manufacture of chemicals and chemical products
		20.1		Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms
			20.14	This class includes the manufacture of chemicals using basic processes, such as thermal cracking and distillation. The output of these processes are usually separate chemical elements or separate chemically defined compounds. This class includes: - manufacture of basic organic chemicals: • acyclic hydrocarbons, saturated and unsaturated • cyclic hydrocarbons, saturated and unsaturated • acyclic and cyclic alcohols • mono- and polycarboxylic acids, including acetic acid • other oxygen-function compounds, including aldehydes, ketones, quinones and dual or poly oxygen-function compounds • synthetic glycerol • nitrogen-function organic compounds, including amines • fermentation of sugarcane, corn or similar, to produce alcohol and esters • other organic compounds, including wood distillation products (e.g. charcoal) etc. - manufacture of synthetic aromatic products - distillation of coal tar

Appendix E – Practical guidance on spatial data sources

This report aims to identify data sources that can be used to populate some components of a quantitative risk assessment model being developed in an EFSA procurement project "Development of probabilistic models for quantitative pathway analysis of plant pests introduction for the EU territory", CFT/EFSA/PLH/2011/01. Following discussion with EFSA, the project team decided data at a spatial scale of NUTS 2 would be a feasible and useful resolution.

Introduction to NUTS (Nomenclature Units for Territorial Statistics)

NUTS are an EU standard for identifying national and sub-national divisions within Members States of the EU. Four NUTS levels are used, NUTS 0 refers to a whole EU MS, while NUTS 1, 2 and 3 refer to increasingly smaller areas within a MS.

At present there are:

97 regions within NUTS 1

270 regions at NUTS 2, and

1,294 regions at NUTS 3 level.

The NUTS regions are broadly based on human populations for comparability, but the threshold figures and upper limits are not always adhered to.

Table E.1.01: Guide for human population within NUTS levels .

Level	Minimum	Maximum
NUTS 1	3 million	7 million
NUTS 2	800,000	3 million
NUTS 3	150,000	800,000

Figure E.1.01: Map of EU NUTS 2 regions (darker shaded regions).

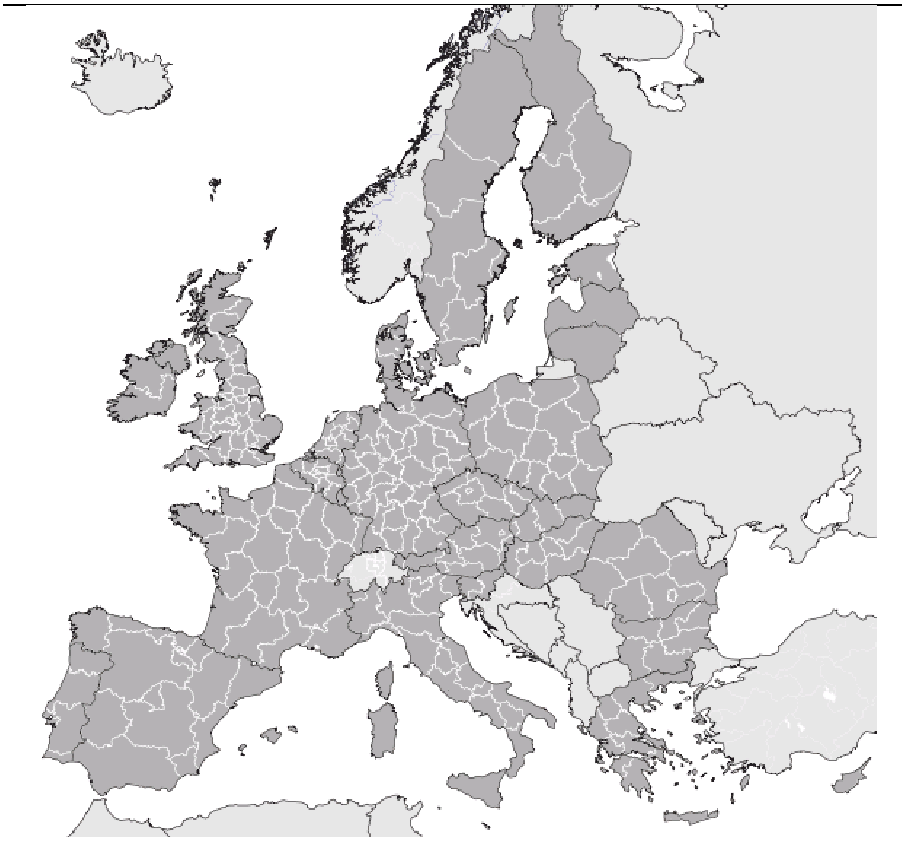


Table E.1.02. EU NUTS descriptors.		
EU member	Description / admin unit for NUTS	Number of NUTS regions
Austria	States	9
Belgium	Provinces (+ Brussels)	11
Bulgaria	Planning regions	6
Croatia	Regions	2
Cyprus	*N/A small country, no NUTS*	1
Czech Republic	Oblasts	8
Germany	Government regions (or equivalent)	39
Denmark	Regions	5
Estonia	*N/A small country, no NUTS2*	1
Spain	17 Autonomous communities and 2 autonomous cities	19
Finland	Large areas	5
France	Regions + DOM	27
Greece	Regions	13
Hungary	Planning and statistical regions	7
Ireland	Regional Assemblies	2
Italy	Regions (Trentino-Alto Adige/Südtirol split into two)	21
Lithuania	*N/A small country, no NUTS2*	1
Luxembourg	*N/A small country, no NUTS2*	1
Latvia	*N/A small country, no NUTS2*	1
Malta	*N/A small country, no NUTS*	1
Netherlands	Provinces	12
Poland	Voivodeships	16

Portugal	Coordination and development regions + autonomous regions	7
Romania	Regions	8
Sweden	National areas	8
Slovenia	Macroregions	2
Slovakia	Oblasts	4
United Kingdom	Counties (some grouped); Inner and Outer London	37

Source: http://en.wikipedia.org/wiki/Nomenclature_of_Territorial_Units_for_Statistics

Agriculture statistics at regional level

Considerable time was spent searching EUROSTAT for data at NUTS2 level for the case study crops (wheat, apples, plums, oranges). The following sites were found of partial use:

http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Agriculture_statistics_at_regional_level

http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database

Figure E.1.02 shows fields in the database from which data can be extracted. Data at a regional level within the EU is available for the following crops:

- Cereals for the production of grain (including rice and seed)
- Cereals (excluding rice)
- Wheat (including spelt) *
- Common wheat and spelt *
- Durum wheat
- Rye
- Barley
- Grain maize
- Rice
- Dried pulses and protein crops for the production of grain (including seed and mixtures of cereals and pulses)
- Potatoes (including early potatoes and seed potatoes)
- Sugar beet (excluding seed)
- Oilseeds
- Rape and turnip seed
- Sunflower seed

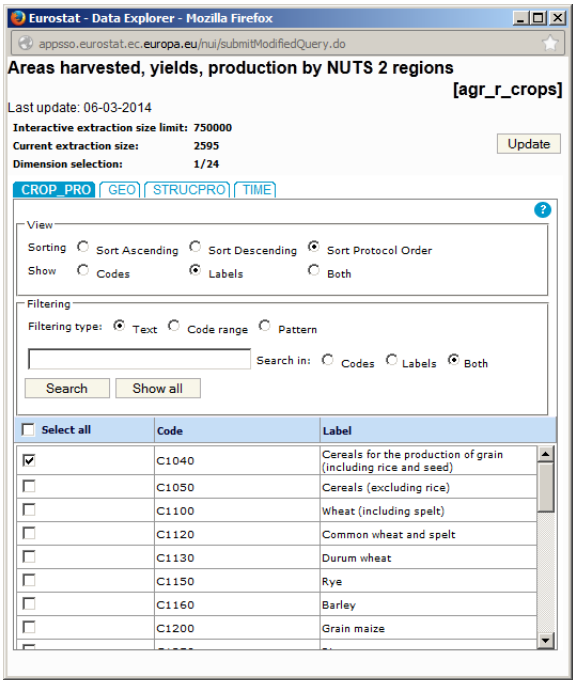
- Linseed (oil flax)
- Soya
- Cotton seed
- Tobacco
- Green maize
- Fruit trees (excluding olives and citrus fruit) *
- Berries (excluding strawberries)
- Vineyards
- Olive trees

Crops marked * are relevant to the project case study crops.

Figure E.1.02a illustrates the user interface for selecting particular crops within the regional agricultural database. The spatial scale is selected by choosing groups (i.e. all) or selected individual regions at the NUTS 0 to 2 (or 3) scale (Figure E.1.02b). Production ('000 of tonnes), yields ('00 kg ha^{-1}) or area harvested ('000 ha) can be selected (Figure E.1.02c) and finally the year for which data is required is selected 1975 – 2013 (Figure E.1.02d).

Figure E.1.02: Database fields for regional agricultural statistics

Figure E.1.02a: Selection of crop



Figures E.1.02b: Selection of geographic unit (NUTS)

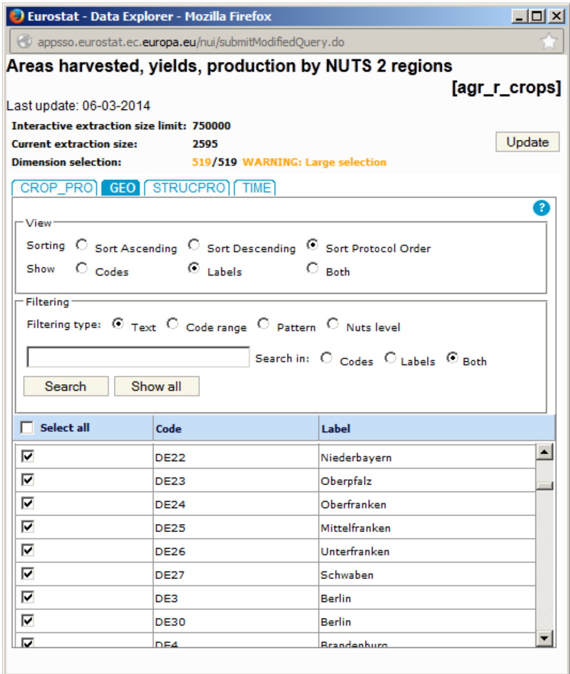


Figure E.1.02c: Selection of production, yield or area

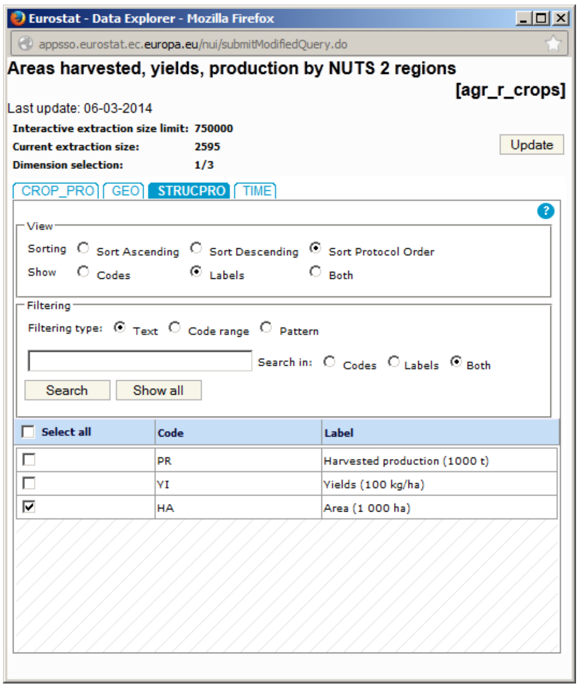


Figure E.1.02d: Selection of year (1975- 2013)

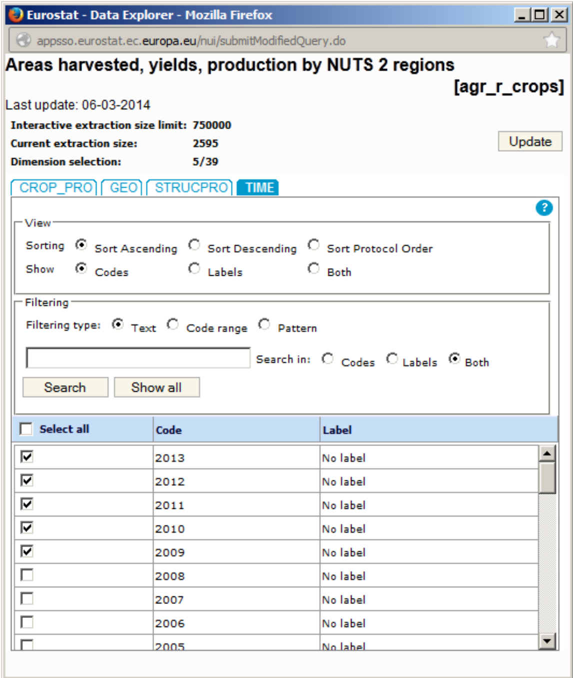
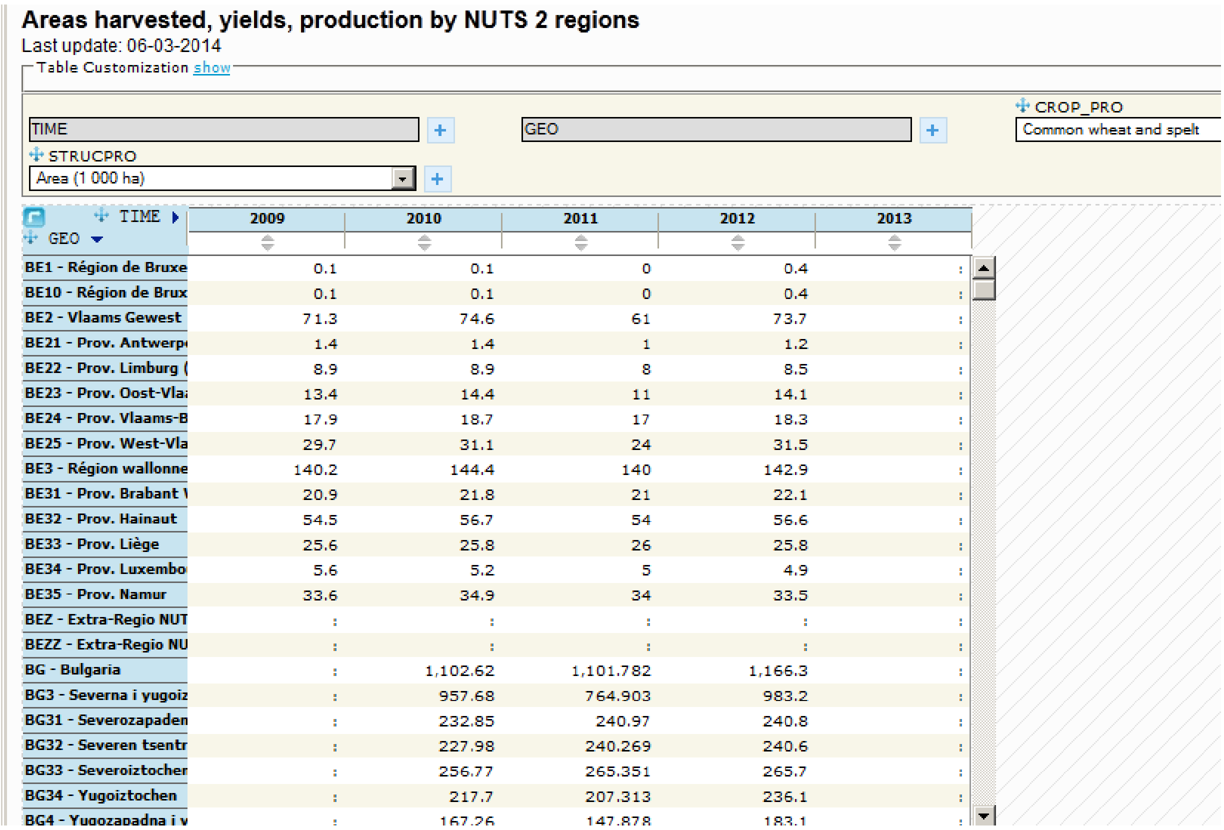


Figure E.1.03 shows a screen shot of the area of common wheat and spelt grown in EU NUTS regions each year from 2009 until 2013. (At the time of searching, only NUTS0 data were available for 2013).

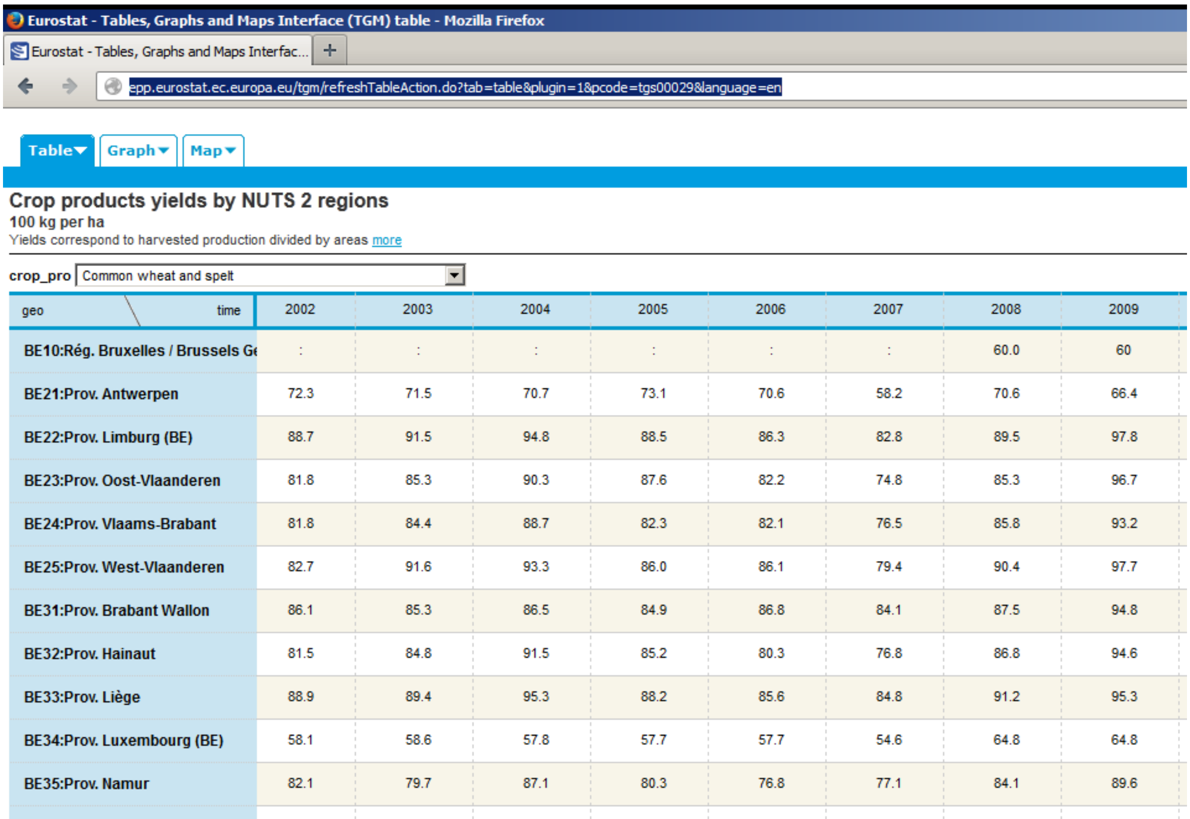


Areas harvested, yields, production by NUTS 2 regions
Last update: 06-03-2014
Table Customization show
TIME | GEO | CROP_PRO: Common wheat and spelt
STRUCPRO: Area (1 000 ha)

GEO \ TIME	2009	2010	2011	2012	2013
BE1 - Région de Bruxe	0.1	0.1	0	0.4	:
BE10 - Région de Brux	0.1	0.1	0	0.4	:
BE2 - Vlaams Gewest	71.3	74.6	61	73.7	:
BE21 - Prov. Antwerp	1.4	1.4	1	1.2	:
BE22 - Prov. Limburg (	8.9	8.9	8	8.5	:
BE23 - Prov. Oost-Vla	13.4	14.4	11	14.1	:
BE24 - Prov. Vlaams-B	17.9	18.7	17	18.3	:
BE25 - Prov. West-Vla	29.7	31.1	24	31.5	:
BE3 - Région wallonne	140.2	144.4	140	142.9	:
BE31 - Prov. Brabant \	20.9	21.8	21	22.1	:
BE32 - Prov. Hainaut	54.5	56.7	54	56.6	:
BE33 - Prov. Liège	25.6	25.8	26	25.8	:
BE34 - Prov. Luxembo	5.6	5.2	5	4.9	:
BE35 - Prov. Namur	33.6	34.9	34	33.5	:
BEZ - Extra-Regio NUT	:	:	:	:	:
BEZZ - Extra-Regio NU	:	:	:	:	:
BG - Bulgaria	:	1,102.62	1,101.782	1,166.3	:
BG3 - Severna i yugoiz	:	957.68	764.903	983.2	:
BG31 - Severozapaden	:	232.85	240.97	240.8	:
BG32 - Severen tsentr	:	227.98	240.269	240.6	:
BG33 - Severoiztocher	:	256.77	265.351	265.7	:
BG34 - Yugoiztochen	:	217.7	207.313	236.1	:
BG4 - Yugozapadna i v	:	167.26	147.878	183.1	:

Figure E.1.03: Eurostat data (screen shot) for area ('000 ha) of "common wheat and spelt" at subnational level

The data shown in the database illustrated in Figures E.1.03 and E.1.04 are used to generate maps such as that illustrated in Figure E.1.05.



geo \ time	2002	2003	2004	2005	2006	2007	2008	2009
BE10:Rég. Bruxelles / Brussels Ge	:	:	:	:	:	:	60.0	60
BE21:Prov. Antwerpen	72.3	71.5	70.7	73.1	70.6	58.2	70.6	66.4
BE22:Prov. Limburg (BE)	88.7	91.5	94.8	88.5	86.3	82.8	89.5	97.8
BE23:Prov. Oost-Vlaanderen	81.8	85.3	90.3	87.6	82.2	74.8	85.3	96.7
BE24:Prov. Vlaams-Brabant	81.8	84.4	88.7	82.3	82.1	76.5	85.8	93.2
BE25:Prov. West-Vlaanderen	82.7	91.6	93.3	86.0	86.1	79.4	90.4	97.7
BE31:Prov. Brabant Wallon	86.1	85.3	86.5	84.9	86.8	84.1	87.5	94.8
BE32:Prov. Hainaut	81.5	84.8	91.5	85.2	80.3	76.8	86.8	94.6
BE33:Prov. Liège	88.9	89.4	95.3	88.2	85.6	84.8	91.2	95.3
BE34:Prov. Luxembourg (BE)	58.1	58.6	57.8	57.7	57.7	54.6	64.8	64.8
BE35:Prov. Namur	82.1	79.7	87.1	80.3	76.8	77.1	84.1	89.6

Figure E.1.04: Eurostat data (screen shot) of annual wheat yield at NUTS 2 resolution: 2002-2009

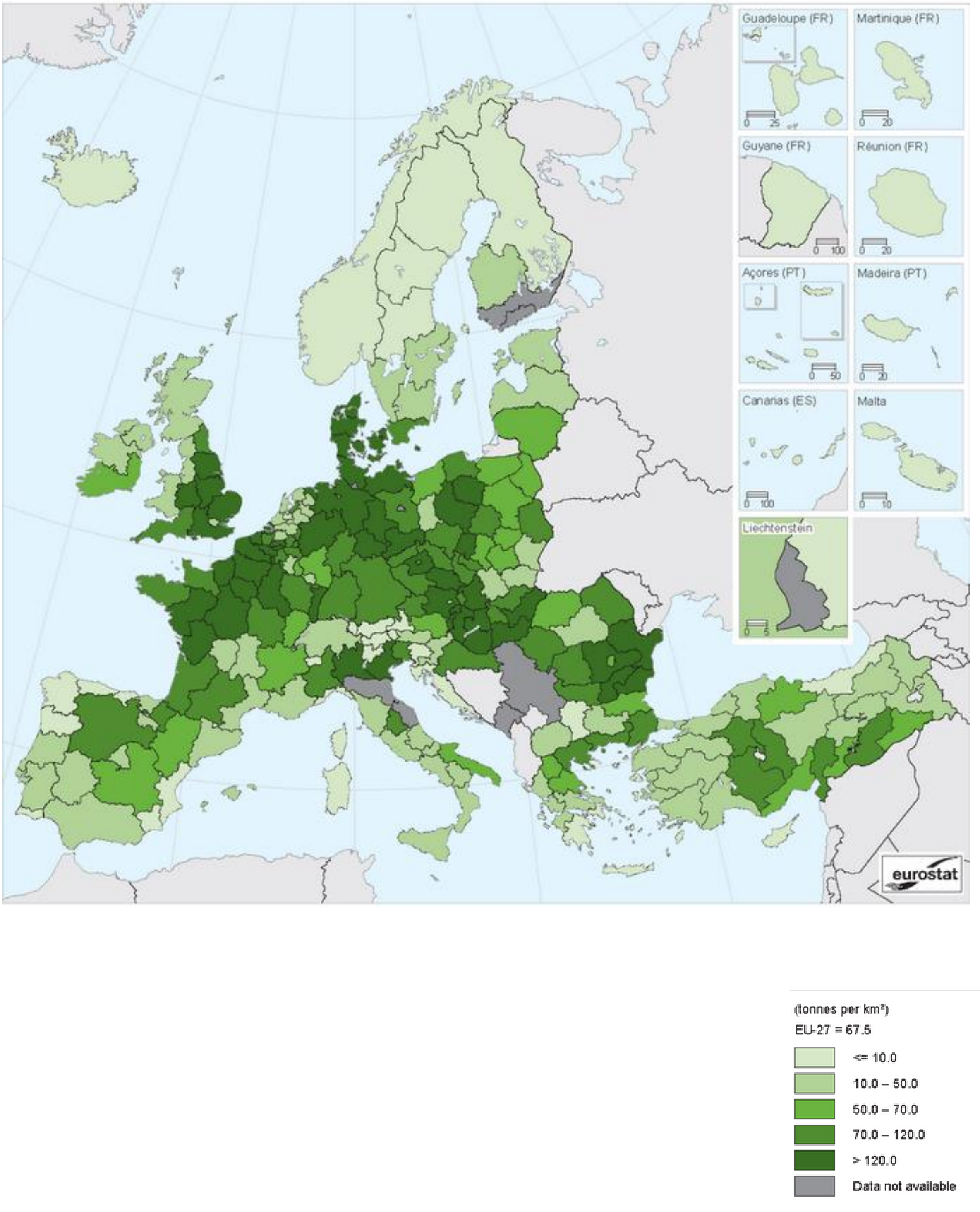


Figure E.1.05: Harvested production of cereals (including rice), by NUTS2 regions, 2011 ([1])

Variation of wheat yield across the EU

An EC report on EU cereal production (European Commission EU FADN, 2013) showed common wheat yield varies widely within the EU. In Greece and Estonia yield is usually around 3 t/ha, while farms in the UK regularly report over 8 t/ha. Denmark, France and Germany are other high-yield producers. The average yield in 2009 was 5.7 t/ha, 4% lower than in the preceding year. A further decrease in yields occurred in 2010, but yields were estimated to have picked up to 5.2 t/ha in 2011. The average yield for durum wheat was 3.3 t/ha in 2008, slightly less (-5%) than the year before. Italy was very close to the average, with Spain and Greece at around 3 t/ha in 2009. French durum wheat yields were significantly higher, at almost 5 t/ha.

TABLE E.1.03: EU MS wheat yields, arranged by mean yield (tonnes /ha)

EU MS	2010	2011	2012	Min	Mean	Max
Belgium	8.8272	8.4046	8.3378	8.34	8.52	8.83
Netherlands	8.9092	7.7812	8.5870	7.78	8.43	8.91
Ireland	8.5990	9.8620	6.3061	6.31	8.26	9.86
Belgium-Luxembourg	7.9813	7.9813	7.9813	7.98	7.98	7.98
United Kingdom	7.6730	7.7486	6.6571	6.66	7.36	7.75
Germany	7.3102	7.0193	7.3283	7.02	7.22	7.33
Denmark	6.6264	6.4672	7.3687	6.47	6.82	7.37
France	6.4419	6.1788	7.5992	6.18	6.74	7.60
Luxembourg	5.9586	5.5290	5.8665	5.53	5.78	5.96
Sweden	5.3966	5.3786	6.2379	5.38	5.67	6.24
Malta	5.3333	4.7241	5.7143	4.72	5.26	5.71
Slovenia	4.8044	5.1770	5.4376	4.80	5.14	5.44
Austria	5.0117	5.8549	4.1385	4.14	5.00	5.85
Czech Republic	4.9923	5.6921	4.3155	4.32	5.00	5.69
Croatia	4.0415	5.2237	5.3473	4.04	4.87	5.35
Poland	3.9432	4.1348	4.1438	3.94	4.07	4.14
Norway	4.5970	3.8511	3.6960	3.70	4.05	4.60

Italy	3.7421	3.8335	4.1324	3.74	3.90	4.13
Lithuania	3.3045	3.3914	4.7829	3.30	3.83	4.78
Hungary	3.7038	4.1994	3.5183	3.52	3.81	4.20
Slovakia	3.5050	4.5197	3.2860	3.29	3.77	4.52
Bulgaria	3.5992	3.9191	3.7596	3.60	3.76	3.92
Finland	3.4299	3.8288	3.9028	3.43	3.72	3.90
Latvia	3.4617	3.0462	4.3411	3.05	3.62	4.34
Estonia	2.7368	2.7960	3.9019	2.74	3.14	3.90
Greece	3.2609	3.1287	2.7852	2.79	3.06	3.26
Spain	3.0498	3.4475	2.6439	2.64	3.05	3.45
Romania	2.7000	3.6650	2.6593	2.66	3.01	3.67
Portugal	1.4305	1.3669	1.0766	1.08	1.29	1.43

Alternative sources for crop area at NUTS 2 (non-Eurostat)

NUTS2 level data on the area grown for the key case study crops are not readily available from Eurostat. Fortunately indicative global distribution maps of the area harvested (hectares per km^{-2}) and yield (tonnes per km^{-2} of production) for a number of crops are available following work by Monfreda *et al.* (2008) using data from a McGill University website.

ARC GIS was used to plot the area of case study crops on a 5 minute latitude x 5 minute longitude map and overlay EU NUTS2 boundaries (Figures E.1.07a – d). Tables generated within ARC GIS and output as Excel tables, indicating the estimated area of harvested case study crops, can provide data for use within the projects quantitative model. A sample screen shot of such a spreadsheet is shown as Figure E.1.06.

Figure E.1.06: Sample screen shot of data within Excel from ARC GIS describing case study crop area within NUTS 2 regions

A	B		C	D		E		F
NUTS_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
EL21	131	0.909715	0	0.014	0.014	0.005084	0.004622	0.666
EL22	20	0.138888	0	0.007	0.007	0.00255	0.002012	0.051
EL23	159	1.104158	0	0.014	0.014	0.003472	0.00386	0.552
EL24	208	1.444433	0	0.014	0.014	0.003952	0.004153	0.822
EL25	206	1.430544	0	0.003	0.003	0.000432	0.000712	0.089
EL30	40	0.277776	0	0.014	0.014	0.0071	0.005704	0.284
EL41	40	0.277776	0	0.014	0.014	0.00595	0.004653	0.238
EL42	38	0.263887	0	0.009	0.009	0.001868	0.00208	0.071

The tables are provided as Excel spreadsheets accompanying this report. Table E.1.04 provides a key to the data in the spreadsheets.

Table E.1.04: Key to data generated from ARC GIS estimating crop area harvested in NUTS 2 regions for case study crops - based on Monfreda *et al.* (2008) using data from McGill University

Highlight label	Column Title	Explanation
A	NUTS_ID	NUTS code identifier (generally 2 letters to identify the EU Member State followed by 2 digits).
B	COUNT	Number of grid cells within the NUTS regions.
C	MIN	Minimum value of a cell within the NUTS region. Here values are the area of crops harvested. Generally there will always be a zero here indicating that not all cells in a region will grow the crop.
D	MAX	Maximum value of a cell within the NUTS regions.
E	MEAN	Mean value of all cell within the NUTS region.
F	SUM	Sum of values for the NUTS region (= B x E). *This is the key value for use in the project and shows a figure representing estimated area grown in each NUTS region for case study crops. Note this has unspecified units (see text after Figure E.1.07d).*

Figure E.1.07 a-d: Estimated harvested area of case study crops at subnational levels within the EU (based on Monfreda *et al.*, 2008)

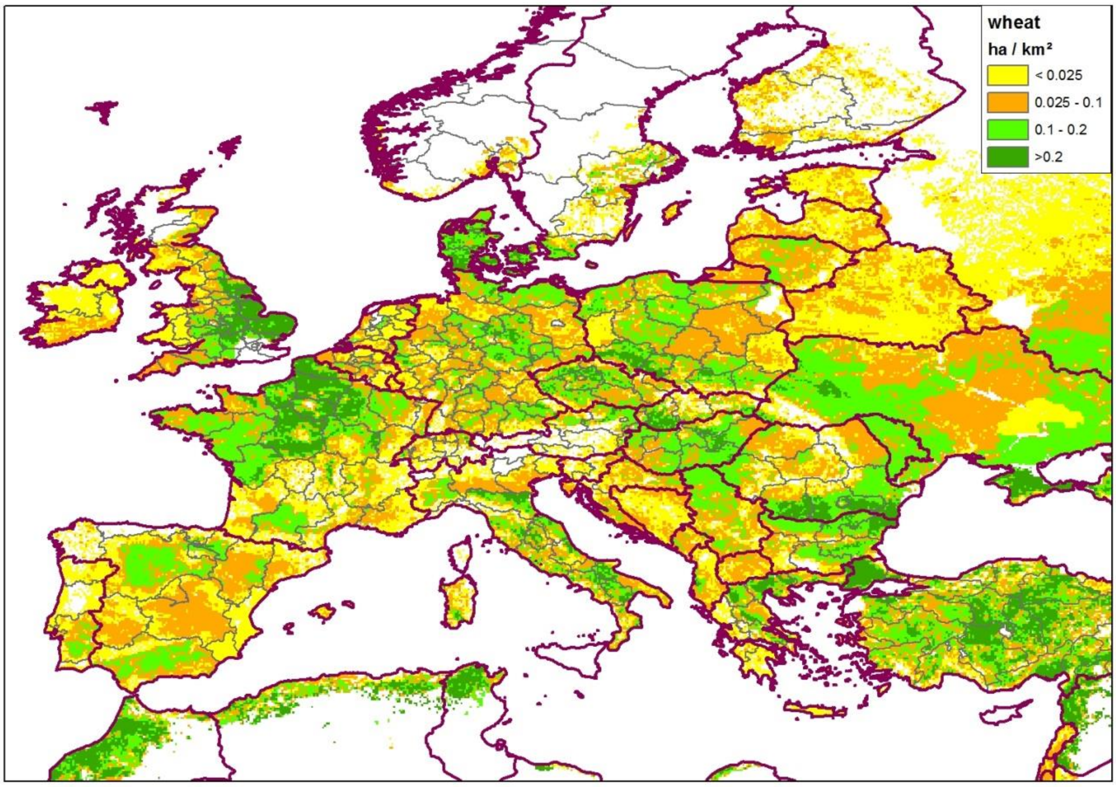


Figure E1.07a: Wheat

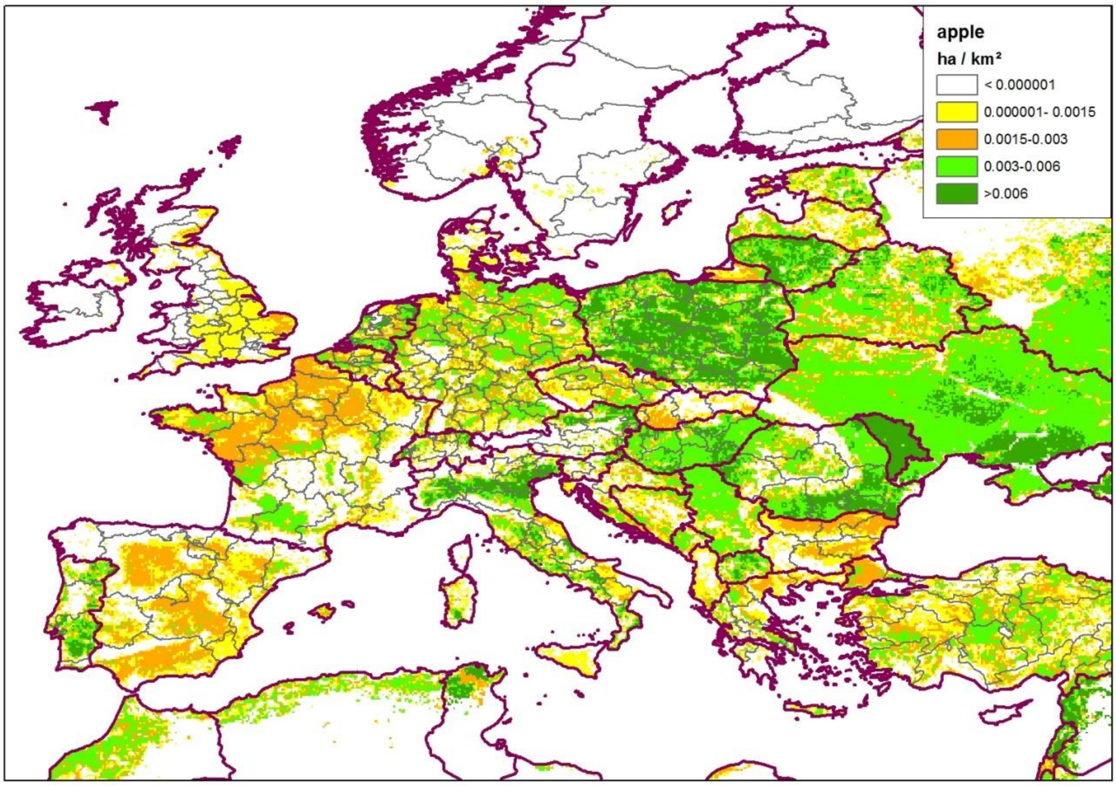


Figure E.1.07b: Apples

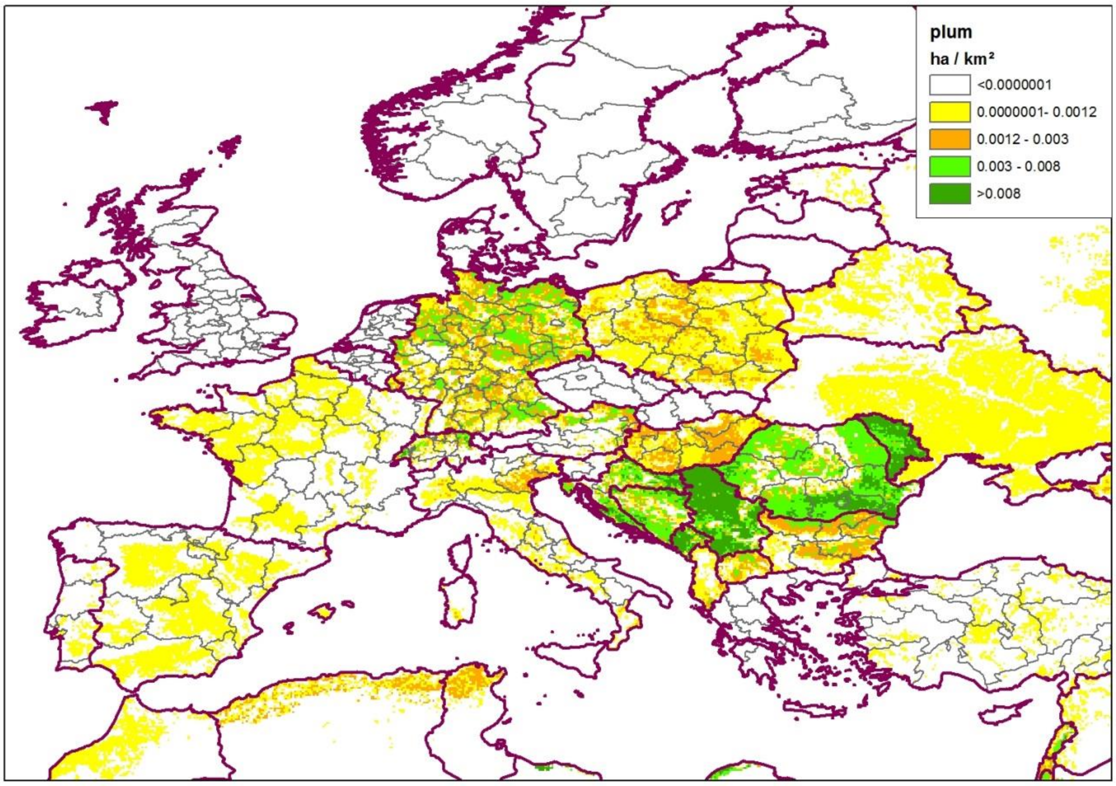


Figure E.1.07c: Plums (data lacking for UK, Low Countries and others)

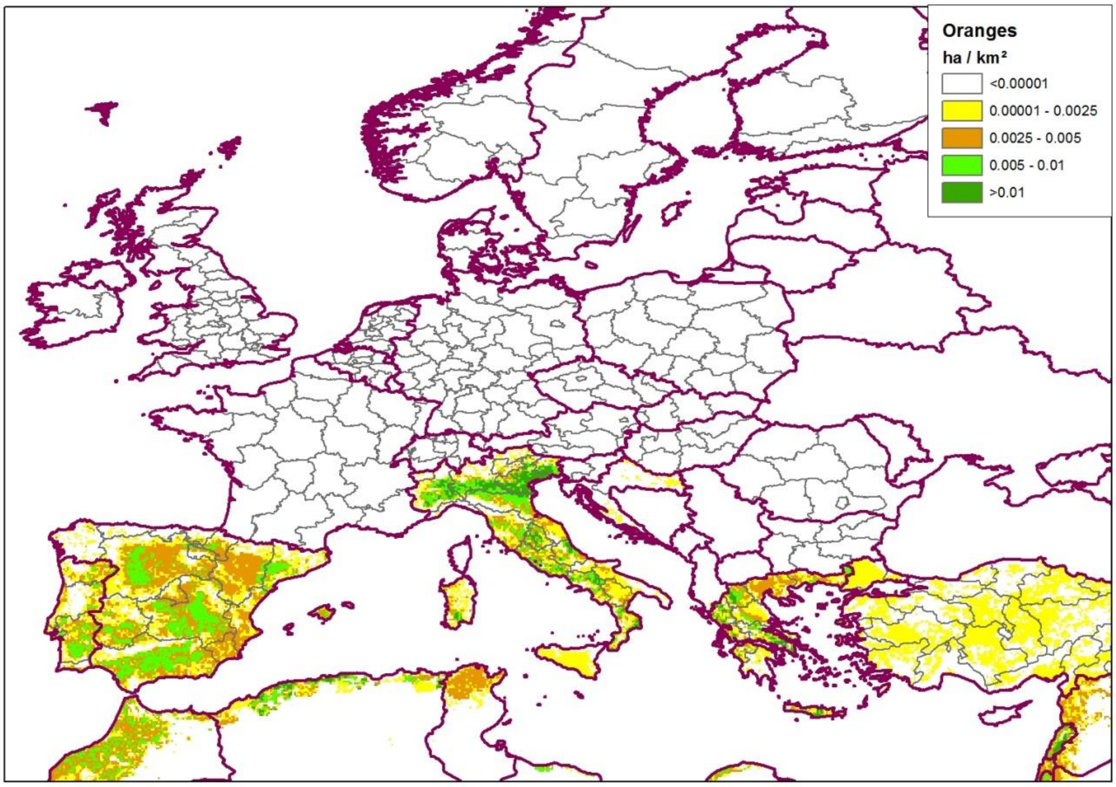


Figure E.1.07d: Oranges (data lacking for France and other MS)

The column labelled "AREA" in the table output from ARC GIS does not represent an SI unit of area such as hectares (ha) but can be used as an index, allowing NUTS2 regions to be identified with the greatest area of case study crops grown.

Thus for wheat, FR24, ES41 and RO31 are the NUTS regions with the largest wheat area planted (Fig. E.1.08a). The largest areas of apple are found in RO21, PL34 and LV00 (Fig. E.1.08b). The largest area of plums are found in RO31, RO22 and RO21 (Fig. E.1.08c) and the largest area of oranges are found in ES42, ES61 and ES41 (Fig. E.1.08d).

Figure E.1.08 a-d: Sample screen shots of data within Excel from ARC GIS ranking case study crop areas within NUTS2 regions

Figure E.1.08a: Wheat

EFSA QPRA								
GIS OUTPUT - WHEAT								
NUTS_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
FR24	679	4.71524	0	0.38	0.38	0.18964	0.08401	128.764
ES41	1464	10.1666	0	0.171	0.171	0.06854	0.05126	100.341
RO31	572	3.97219	0	0.281	0.281	0.14918	0.08888	85.331
FR22	346	2.40276	0.004	0.327	0.323	0.23406	0.06147	80.986
ES61	1248	8.6666	0	0.137	0.137	0.06468	0.04572	80.724
LT00	1320	9.16659	0	0.167	0.167	0.05473	0.04178	72.246
RO22	562	3.90275	0	0.357	0.357	0.12482	0.07744	70.15
UKH1	234	1.62499	0.076	0.364	0.288	0.28102	0.06006	65.758
FR21	446	3.0972	0	0.29	0.29	0.14735	0.07032	65.72
FR51	542	3.76386	0.013	0.209	0.196	0.11067	0.02883	59.981
FR53	429	2.97914	0	0.234	0.234	0.13934	0.0593	59.777
RO41	475	3.29858	0	0.266	0.266	0.12083	0.09136	57.393
PL51	359	2.49304	0	0.292	0.292	0.15477	0.08405	55.562
FR26	537	3.72914	0	0.325	0.325	0.09766	0.07997	52.443
PL41	568	3.94441	0	0.249	0.249	0.08951	0.03745	50.841

Figure E.1.08b: Apples

EFSA QPRA								
GIS OUTPUT - APPLES								
NUTS_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
RO21	630	4.37497	0	0.025	0.025	0.00295	0.00246	1.858
PL34	395	2.74303	0	0.01	0.01	0.00466	0.00269	1.842
LV00	1361	9.45131	0	0.01	0.01	0.00133	0.00138	1.815
PL63	358	2.48609	0	0.01	0.01	0.00485	0.00292	1.737
PL51	359	2.49304	0	0.009	0.009	0.00477	0.00266	1.713
PT18	453	3.14581	0	0.009	0.009	0.00374	0.00286	1.696
ITH3	287	1.99304	0	0.008	0.008	0.00572	0.00284	1.643
RO41	475	3.29858	0	0.007	0.007	0.00339	0.00211	1.609
ES42	1201	8.34021	0	0.003	0.003	0.00125	0.00087	1.505
ES41	1464	10.1666	0	0.003	0.003	0.00102	0.00086	1.491
HU33	305	2.11804	0	0.007	0.007	0.00475	0.00109	1.448
HU32	306	2.12498	0	0.006	0.006	0.00469	0.00098	1.435
ES61	1248	8.6666	0	0.003	0.003	0.00114	0.00087	1.419
RO42	532	3.69442	0	0.007	0.007	0.0026	0.00238	1.381
RO11	589	4.09025	0	0.006	0.006	0.00234	0.00183	1.379

Figure E.1.08c: Plums

2	EFSA QPRA								
3	GIS OUTPUT - PLUMS								
4	NUTS_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
5	RO31	572	3.97219	0	0.01	0.01	0.0056	0.00326	3.203
6	RO22	562	3.90275	0	0.01	0.01	0.0055	0.00304	3.089
7	RO21	630	4.37497	0	0.008	0.008	0.00364	0.00268	2.296
8	HR04	527	3.65969	0	0.023	0.023	0.00408	0.00353	2.151
9	RO41	475	3.29858	0	0.02	0.02	0.00438	0.00273	2.080
10	RO42	532	3.69442	0	0.026	0.026	0.00349	0.00356	1.859
11	RO11	589	4.09025	0	0.008	0.008	0.003	0.00229	1.767
12	RO12	570	3.9583	0	0.008	0.008	0.00225	0.0023	1.283
13	HR03	336	2.33331	0	0.013	0.013	0.00356	0.00326	1.197
14	DE40	571	3.96525	0	0.005	0.005	0.0018	0.00126	1.028
15	DE80	430	2.98609	0	0.004	0.004	0.00215	0.00093	0.924
16	DEE0	384	2.66665	0	0.005	0.005	0.00218	0.00104	0.838
17	PL12	672	4.66663	0	0.002	0.002	0.00103	0.00051	0.689
18	ES42	1201	8.34021	0	0.001	0.001	0.00057	0.0005	0.682

Figure E.1.08d: Oranges

2	EFSA QPRA								
3	GIS OUTPUT - Oranges								
4	NUTS_ID	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM
5	ES42	1201	8.3402	0	0.007	0.007	0.00366	0.00233	4.395
6	ES61	1248	8.6666	0	0.007	0.007	0.00346	0.0025	4.319
7	ES41	1464	10.1666	0	0.007	0.007	0.00293	0.00223	4.284
8	ITH3	287	1.9930	0	0.013	0.013	0.00926	0.00459	2.657
9	ES24	736	5.1111	0	0.007	0.007	0.00276	0.00183	2.033
10	ITC4	389	2.7014	0	0.013	0.013	0.00464	0.00471	1.804
11	PT18	453	3.1458	0	0.009	0.009	0.00361	0.00274	1.634
12	ITC1	419	2.9097	0	0.013	0.013	0.00368	0.00444	1.541
13	ES43	625	4.3402	0	0.007	0.007	0.00246	0.00218	1.536
14	ITH5	363	2.5208	0	0.013	0.013	0.00416	0.00377	1.51
15	ITI4	252	1.7500	0	0.013	0.013	0.00485	0.00358	1.221
16	ES51	483	3.3541	0	0.007	0.007	0.00209	0.00251	1.009
17	ITI1	355	2.4653	0	0.012	0.012	0.00266	0.00275	0.943
18	ITF3	198	1.3750	0	0.013	0.013	0.00463	0.00403	0.917

Population density at NUTS

An estimate of the final destination of commodities for consumption could reasonably be expected to be determined by population density. Eurostat provides population density data at up to a resolution of NUTS 3 and is available for download at ….

http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

Figure E.1.09 shows a screen shot for selecting NUTS regions and Figure E.1.10 shows output which can be downloaded in various formats.

Figure E.1.09: EU Population density at subnational level – Eurostat database interface for selection of spatial scale

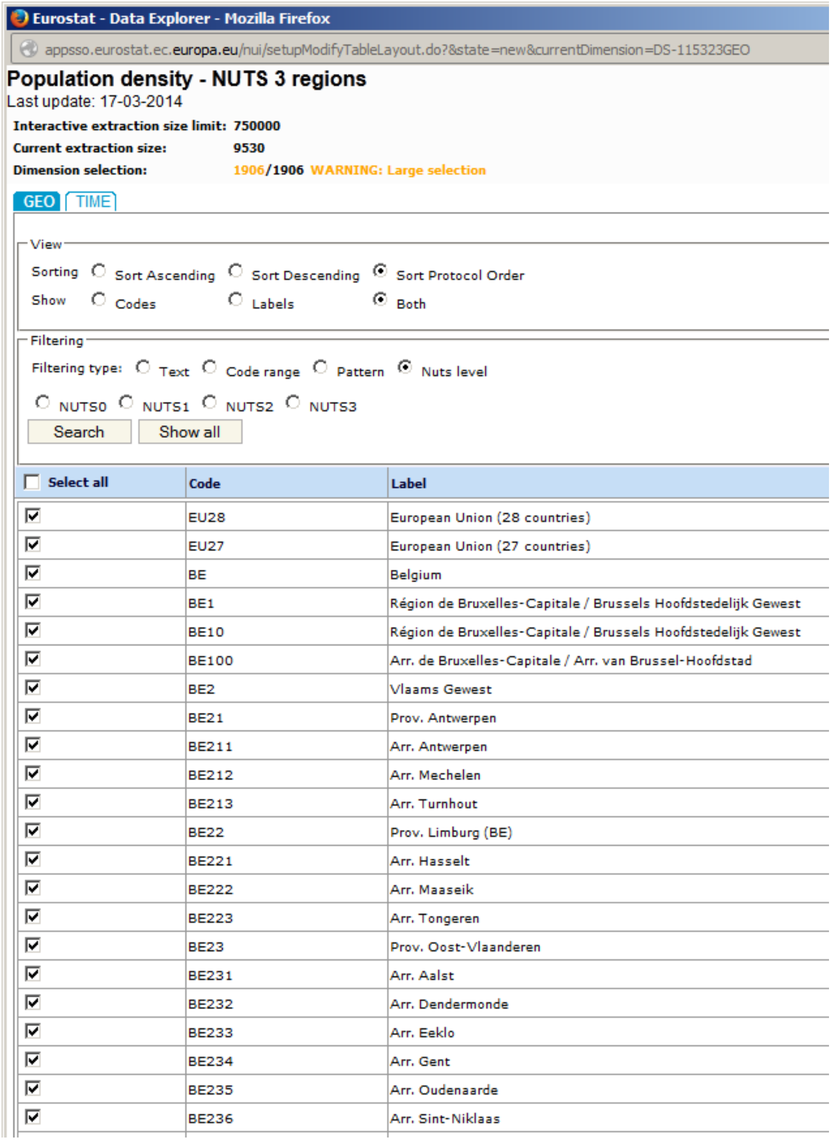


Figure E.1.10: Sample screen shot for subnational EU population density

Population density - NUTS 3 regions

Last update: 17-03-2014

Table Customization hide

Labeling: Codes Labels Both Dimension specific

Cell Formatting 1.234,56 1,234.56 1 234.56

Hide empty lines Hide flags/footnotes

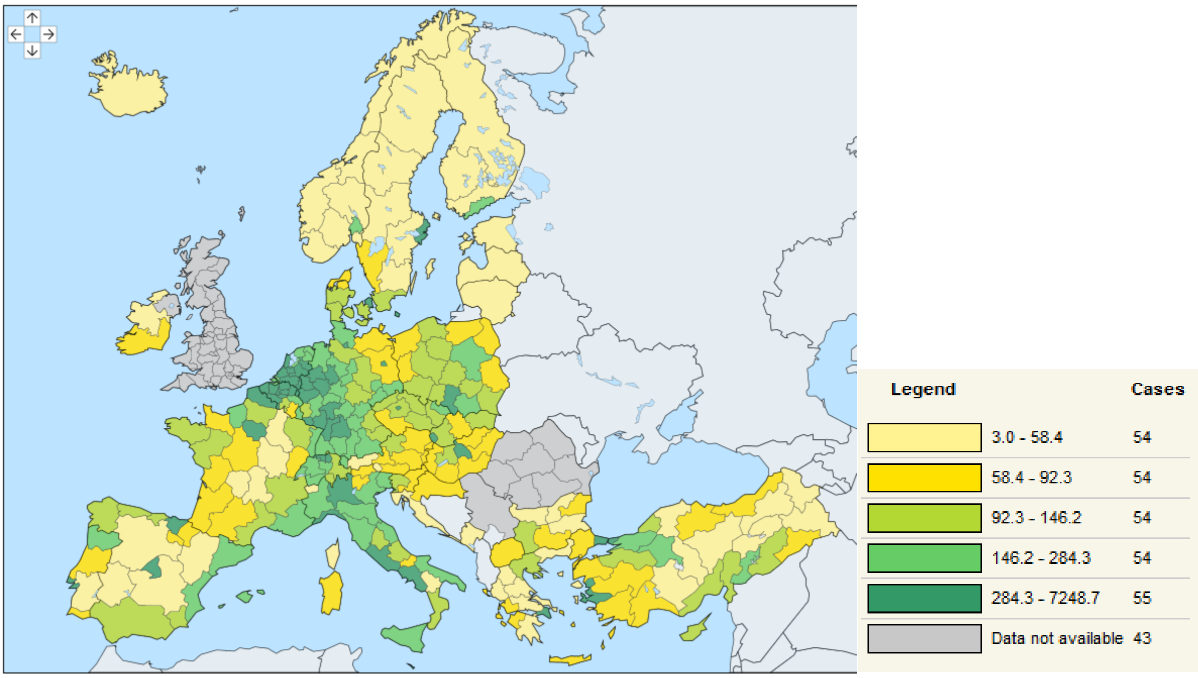
TIME + GEO

GEO \ TIME	2008	2009	2010	2011	2012
EU28 - European Union	115.1 (e)	115.5 (e)	115.7 (e)	116.0 (e)	116.3 (e)
EU27 - European Union	115.6 (e)	116.0 (e)	116.2 (e)	116.5 (e)	116.9 (e)
BE - Belgium	353.1	356.0	358.7	364.3	367.0
BE1 - Région de Bruxe	6,574.6	6,702.1	6,902.0	7,131.1	7,248.7
BE10 - Région de Brux	6,574.6	6,702.1	6,902.0	7,131.1	7,248.7
BE100 - Arr. de Bruxel	6,574.6	6,702.1	6,902.0	7,131.1	7,248.7
BE2 - Vlaams Gewest	462.8	466.2	467.9	475.2	478.2
BE21 - Prov. Antwerp	617.3	622.5	619.2	637.4	642.6
BE211 - Arr. Antwerpe	1,020.5	1,028.8	999.8	1,056.4	1,066.2
BE212 - Arr. Mechelen	642.2	647.4	647.7	660.7	665.0
BE213 - Arr. Turnhout	320.7	323.7	326.5	329.5	331.7
BE22 - Prov. Limburg (	346.7	349.1	351.8	355.7	357.6
BE221 - Arr. Hasselt	452.6	456.2	459.1	465.1	468.0
BE222 - Arr. Maaseik	263.6	265.5	268.0	270.3	271.7
BE223 - Arr. Tongeren	311.8	313.4	315.4	318.8	319.9
BE23 - Prov. Oost-Vla	480.1	484.2	485.7	493.1	495.9
BE231 - Arr. Aalst	576.7	581.0	587.7	592.9	597.3
BE232 - Arr. Denderm	569.9	573.2	571.8	582.1	585.3
BE233 - Arr. Eeklo	244.4	246.0	248.3	249.9	250.8
BE234 - Arr. Gent	555.9	561.6	565.9	573.1	575.8
BE235 - Arr. Oudenaar	283.8	286.0	288.4	288.9	290.4
BE236 - Arr. Sint-Nikla	511.1	515.5	505.5	525.5	529.0
BE24 - Prov. Vlaams-B	506.9	510.9	516.1	520.0	523.5
BE241 - Arr. Halle-Vilv	624.0	628.8	634.9	640.7	645.9
BE242 - Arr. Leuven	412.0	415.3	419.6	422.1	424.4
BE25 - Prov. West-Vla	368.1	369.5	370.8	374.6	376.1
BE251 - Arr. Brugge	421.7	422.2	420.7	429.8	431.7
BE252 - Arr. Diksmuid	136.2	137.2	138.4	139.0	139.9

http://epp.eurostat.ec.europa.eu/statistics_explained/images/e/e4/Population_density%2C_by_NUTS_2_regions%2C_2008.PNG

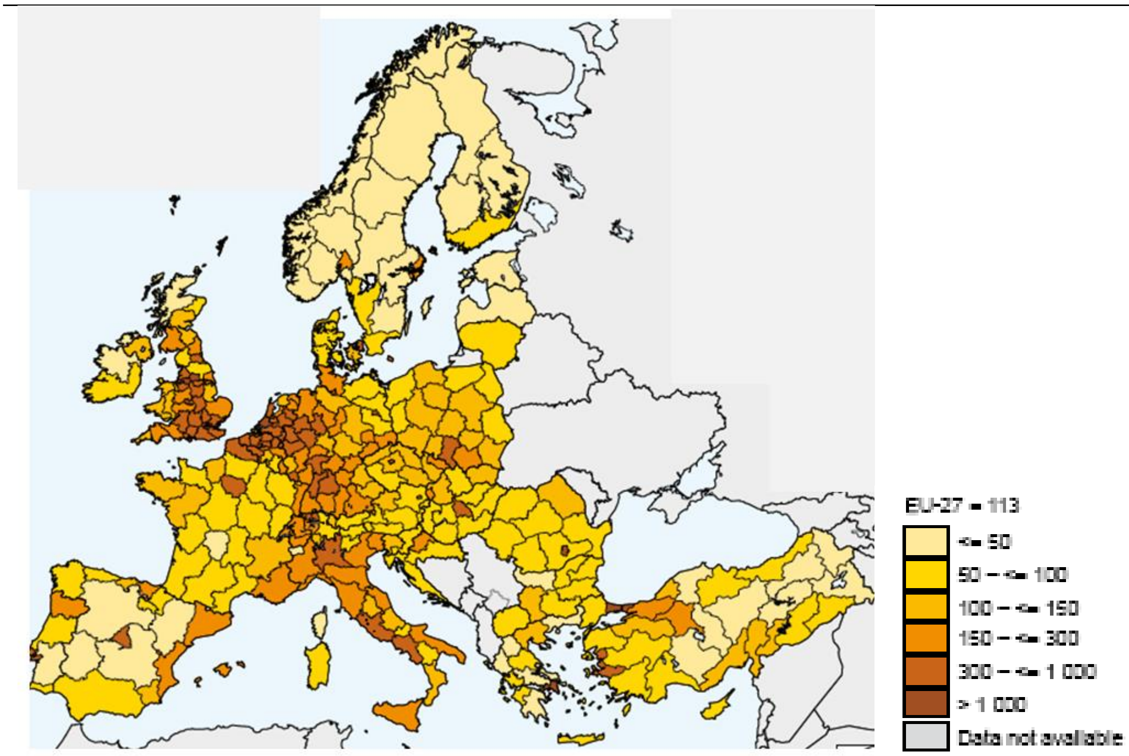
Maps illustrating EU population density are available from the Eurostat website (e.g. Figure E.1.11). The most recent data (2012) are not available for some countries (43 NUTS2 regions missing, Figure E.1.11a). However, data from 2008 is more comprehensive (Figure E.1.11b).

Figure E.1.11a: EU Population density by NUTS region (Data for 2012)



Source: http://epp.eurostat.ec.europa.eu/tgm/mapToolClosed.do?tab=map&init=1&plugin=1&language=en&pcode=tgs00024&toolbox=types#

Figure E.1.11b: EU Population density by NUTS region (Data for 2008)



A spreadsheet with annual population density data for the years 2008 to 2012 at the NUTS2 spatial scale accompanies this report.

Appendix F – Practical guidance on information gathering and helpful data sources

A structured technique for gathering information for pest risk analysis used by Fera

Introductory notes: There may often be old books / journals / websites which contain really useful background information, but always think about how up to date the information is. For a specific topic, literature searches are the first area for consideration and should yield the most up to date information. Ensure these are done in discussion with the Information Centre staff; the specialist can often unearth information which you may not find yourself. If a quick search is needed use the links under the Information Centre page on the intranet.

No.	Question	Answer	Go to
1.	Are you searching for information about a particular pest?		2
	or for information about a particular plant, crop or commodity?		13
	or for information about a geographical area?		15
2.	**Check the name of the pest, look for synonyms and misspellings.**		

General

CABI CPC (Crop Protection Compendium)

CABI FC (Forestry Compendium)

Plant Health Information Warehouse (PHIW)

EPPO PQR – Plant Quarantine Information Retrieval system

The NCBI Entrez Taxonomy Homepage

Fera Registered files (PPH and PPP),

Invertebrate Pests

CABI Arthropod Name Index

Wood, (1989), Bosik, (1997), Evans, (1961),

Fauna Europaea – online database,

Kloet and Hinks (various years), Anon. (1989), Hollis (1980),

Derwent Publications (Eds.) (1990),

For nematodes try Esser, (1991), but check with Sue Hockland

Diseases

Indexfungorum

MycoBank

Fungal Records Database of Britain and Ireland

Farr et al (undated)

Bradbury (1986)

ICTVdB

DPVWeb

Smith *et al*., 1988

	Have you found the correct name?	Yes	3
		No	4
No.	Question	Answer	Go to
3.	Do you need more information on the pest?	Yes	5
		No	STOP

4. Search Information Centre IPAC computer system – use keywords,

Conduct a literature search on sites such as Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords,

Ask Information Centre staff for an on-line literature search.

Conduct a general internet search e.g. Google.

	Do you have the name of a pest now?	Yes	3
		No	22

Check to see whether there is any information collected already, or a PRA has been written.

General

CABI CPC (Crop Protection Compendium)

CABI FC (Forestry Compendium)

Plant Health Information Warehouse (PHIW)

EPPO PQR – Plant Quarantine Information Retrieval system

EPPO website, EPPO Reporting Service,

Registered files (PPH and PPP),

EPPO QPE (Quarantine Pests for Europe) data sheets / Smith *et al.* (1997)

CABI/EPPO (1998) Distribution maps of quarantine pests for Europe

CABI/CMI/CIE (various years) Distribution maps of pests and diseases

Buczacki *et al.*, 2005

Invertebrate Pests

Fera database INFServb "biology", Fauna Europaea,

Hill, (1983, tropical pests), Hill, (1987, temperate pests).

Diseases

Fungal Records Database of Britain and Ireland

Farr *et al.* (undated)

Cannon *et al.* 1985 (Ascomycetes)

Legon *et al.*, 2005 (Basidiomyctes)

Ellis & Ellis (1985) (Microfungi)

Moore (1959) Pathogenic fungi

Bradbury (1986) (Bacteria)

NCPPB (on PHIW) (Bacteria)

No.	Question	Answer	Go to

ICTVdB (Viruses)
DPVWeb (Viruses)
Baker (1972) (Diseases)
Smith *et al*., 1988 (Diseases)
New Disease Reports
Plant Disease Notes (APS)
Pro-Med Plant Disease Reports

	Do you need more information?	Yes	6
		No	**STOP**

6.	What sort of information do you need?	
Status in legislation		7
Interception Reports		8
Geographic distribution		9
Climate in present geographical distribution		10
	Plant host range	11
	General Pest Biology	12
	Economic importance / commodity imports/exports	18
	Pathways	19

Control options	20
A picture / photo / image	21
Other	17

7. Status in legislation: try sources such as

EC Plant Health Directive 2000/29/EC (pdf online),

EPPO website, EPPO PQR,

Plant Health Information Warehouse (including policy decisions section)

SOCPHIR – Summaries of Overseas Countries Plant Health Import Regulations, IPPC website

EPPO QPE data sheets / Smith et al. (1997).

Do you need more information?	Yes	6
	No	STOP

8. Interception reports: try sources such as

- Diagnosis database (E-diag, CSL database, data from Jan. 1996),
- EPPO Reporting Service,
- eDOMERO (2006 – present), DOMERO 2000 (2000 – 2005), DOMERO 93 (1993 – 2000), Old DOMERO (1988 – 1993), Interception reports (1975-1985: hard copy),
- PHD summaries of PHSI import interceptions,
- EPPO intercepted consignments (PPP 5029 (CL), PPP 6819 (CL)),

No.	Question	Answer	Go to

EUROPHYT – (FIS) CIRCA (online database),

EU interception reports

- EU Notification of interceptions from other EC countries (PPP 6337 (CL), 8688 (CL)),
- EU Notification to EC Commission and Member States of pest and disease interceptions, incidents and outbreaks (PPP 5600 EC/TC (CL), PPP 8257 (CL)),
- Spreadsheet of EU Notifications of findings by NPPOs (1995-2005)
- FVO (Food and Veterinary Office) – online,
- PPH 2948 and 3630 – reports of invertebrates new to the UK
- PPH 3156 – lists and reports of invertebrates (including pest invertebrates) new or invasive in overseas countries (i.e. not UK).

PPP 12043 New UK Disease Records

Pathdiary on the PHIW

Do you need more information?	Yes	6
	No	**STOP**

Geographic distribution: is it native to the UK / Europe?

General sources

CABI/CMI/CIE (various years) Distribution maps of pests and diseases,

CABI/EPPO (1998) Distribution maps of Quarantine Pests for Europe,

CABI CPC, CABI FC, EPPO PQR, EPPO Reporting Service,

Information Centre also has literature on specific geographic regions see:

Plant pests 632

Crops 633.1

Invertebrate pests:

INFServb "biology",

ScaleNet - online, Pest Fruit Flies of the World – online.

Search Information Centre by taxon group – books often look at a specific geographic region, e.g.:

General insect literature 595.7

Aphids 595.752

Coleoptera 595.76

Diptera 595.77

To check for invertebrate pest presence in the UK try Information Centre sections above, but in particular:

- Kloet & Hinks (various years) for insects in general,
- Maitland, Emmett & Heath (1992) for Lepidoptera,
- Evans et al. (1961) for mites, also see J. Starzewski, who has been drafting a more up to date checklist,
- Evans *et al.* (1993) and Luc *et al.* (2005) for nematodes,
- Chandler (ed.) (1998) for Diptera., also online at DipteristsForum.

No.	Question	Answer	Go to

National Biodiversity Network's Species Dictionary – online,

LepIndex – online, Leafmines – online, The Coleopterist – online.

For diseases, please use the same references as in question 5.

Ask Information Centre for an online literature search, including zoological record, (remember that such a search does not pick up any books, or papers published before 1972).

Do you need more information?	Yes	6
	No	STOP

10. Climatic data on a geographical area: try sources such as

HMSO (1972) – for Europe

FAO (1984a & b) and HMSO (1983) – for Africa

FAO (1987a & b) – for Asia

HMSO (1980) – for North America

FAO (1985) – for South America and the Caribbean

Pearce & Smith (1990) – for the world

CLIMEX (on Alan's PC) – uses climatic data from 1931-1960

World Meteorological Organization (WMO) (online)

MET Office – climate averages (online)

Check literature searches for population data e.g. degree day models for invertebrates

Do you need more information	Yes	1 or 6
	No	STOP

11. **Plant host range**: try sources such as

EPPO PQR, PPH and PPP files,

Invertebrate pests: try INFServb "biology"

Search Information Centre by pest order, e.g.:

- Hemiptera 595.75
- Coleoptera 595.76
- Diptera 595.77
- Lepidoptera 595.78

Diseases:

Fungal Records Database of Britain and Ireland

Farr *et al* (undated)

Moore (1959) (Pathogenic fungi)

Bradbury (1986) (Bacteria)

NCPPB (on PHIW) (Bacteria)

ICTVdB (Viruses)

DPVWeb (Viruses)

No.	Question	Answer	Go to
	Do you need more information?	Yes	6
		No	STOP

12. General pest biology: try sources such as

- Search Information Centre IPAC catalogue (use keywords),
- the Internet e.g. CABI CPC, CABI FC,
- Search on Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords
- Ask Information Centre staff for an on-line literature search.

(see also 9 - specialist websites).

Invertebrates: Alford (1991, 1999 and 2007), Arnett (2000),

Hill (1983), Hill (1987), INFServb "biology",

Davidson & Lyon (1987), Metcalf & Metcalf (1993),

For nematodes try Willmott *et al.* (CIH data sheets)

Search filing cabinet (Room 02FA07) pests listed alphabetically by Genus,

Disease: Agrios (2005) (General Plant Pathology text)

Waller et al. (2005) (General Plant Pathology text)

Carlile et al. (2001) (General text on fungi)

		Answer	Go to
	Do you need more information?	Yes	6
		No	STOP

13. Do you have the name of a particular plant, crop or commodity?

Answer	Go to
Yes	14
No	15

14. Information about a plant, crop or commodity: try sources such as

General: De Rougemont (1989), Mabberley (1997),

Anon. (2005), Howes (1974), Tutin *et al.*, (1964-1980),

The International Plant Names Index (online).

Location: Flora of North America (online),

Preston *et al.* (New Atlas of British and Irish Flora) (2002)

Tutin *et al.* (Flora Europaea – 5 volumes) (1964-1980)

Flora Europaea (online), BSBI Atlas (online)

DEFRA Agricultural Census (online)

Information on crop husbandry and growing methods

Search Information Centre by crop e.g.:

Cereals 633.1

Grasses 633.2

Potatoes 633.491

Forest and Aboriculture 634

No.	Question	Answer	Go to

Fruit Growing 634.1/.7

Ornamentals 635.9

Search internet for sites on specific industries.

Economic information on crops / commodities: try sources such as
DEFRA Basic Hort. Stats., FAO Statistics,
The PHSI IMPS (imports) database,
PHSI Imports Summary (PPP 2149 (CL)),
Nix *et al.* (annual), Beaton (annual), Brookes (2005).
Search Information Centre e.g.:
- Agriculture 63
- Farming 631

For information about imports / exports, see also Question 18.

Information about pests on a crop / commodity: try sources such as
EPPO PQR, INFServb "biology",
Search Information Centre by crop – see crop husbandry
Search filing cabinet (Room 02FA07) arranged alphabetically by commodity.
APS compendia of pests and diseases

No.	Question	Answer	Go to
15.	**Do you have the name of a geographic area?**	Yes	16
		No	17

16. Information on geographic areas: try sources such as:

EPPO PQR, INFServb "biology",

Search Information Centre for books by country / region,

Search filing cabinet (Room 02FA07) alphabetical by country.

For information about climate, go to Question 10.

17. Search Information Centre IPAC computer system – use keywords,

Conduct a literature search on sites such as Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords,

Ask Information Centre staff for an on-line literature search.

Conduct a general internet search e.g. Google.

Do you have the information you need now?	Yes	1
	No	22

No.	Question	Answer	Go to

18. **Economic Impact**:
General: try sources such as:

Search Information Centre e.g.:
- Plant pests 632.7/.7
- Insects pests 632.7
- Crop loss assessment 632.03

Search on Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords,
Ask Information Centre staff for an on-line literature search.
See "Disease and yield loss assessment" chapter in Waller *et al*. (2005) and references therein

See also Question 14

Information on the quantity and value of commodity imports and exports: try sources such as:

DEFRA Economics and Statistics department – personal requests may be made through Plant Health Division.
FAO Statistics – the website has data on imports by commodity

Do you need more information?	Yes	6
	No	**STOP**

19. **Pathways**: try sources such as
FAO Statistics – information on imports by commodity
Contact Sam Bishop for information on licensing
Conduct a general internet search e.g. Google for a particular commodity

Do you need more information?	Yes	6
	No	**STOP**

20. Control / Management options: try sources such as

PPH files, Liaison, Chemform,

Whitehead (2006), Tomlin (2003),

Search Information Centre e.g.:

- Control methods 632.93
- Biocontrol 632.937
- Pesticides 632.95

Search on Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords,

Ask the Information Centre staff for an on-line literature search.

Action recommendation files (See Dominic/Helen)

Do you need more information	Yes	1
	No	STOP

No.	Question	Answer	Go to

21. Picture/photo/image of a pest / pests' damage: try sources such as:

Smith & Roy (1996), the PHIW Image Library,

Search the Information Centre IPAC system for slides

Search on Web of Knowledge, INGENTACONNECT and OVID (all through Athens) also Google (Scholar) – use keywords,

Search the World Wide Web, Search in trade press and industry journals,

Ask the Information Centre for an on-line literature search.

Phot database (CSL Intranet)

Do you need more information?	Yes	6
	No	STOP

22. **Go back to the original request and check what is needed**.

Information Sources Commonly Used During Intelligence Gathering

Agrios, G.N. (2005) Plant Pathology. Elsevier Academic Press. *(02FA03//library)*

Alford, D.V. (1991) A colour atlas of pests of ornamental trees, shrubs and flowers. London Wolfe, 448pp. (*Lab. 02F04 and Information Centre: REF 635.9-2.6/.7/ALF*).

Alford, D.V. (1999) A textbook of Agricultural Entomology. Blackwell Science, 314pp. (*Information Centre: REF 632.7/ALF*).

Alford, D.V. (2007) Pests of Fruit Crops – a colour handbook. Mansion Publishing Ltd, pp. (*Lab. 02F04*).

Anon. (1975-1985) Interception reports: Insects & other invertebrates found in plant material imported into England & Wales (compiled by CSL) (*In Room 02FA07*).

Anon. (1989) Invertebrates Of Economic Importance in Britain, Common and Scientific Names. 3rd Edn. HMSO MAFF London, 132pp (*Copy in PRA Library, Room 02FA06 and older copy in Information Centre: REF 03:594/5 Gre*).

Anon. (2005) The RHS Plant Finder 04 – 05, 17th Edn., Dorling Kindersley Books, 952pp (*Information Centre 085:ROY and information also available online*).

Anon. (1999) The New Royal Horticultural Society Dictionary of Gardening (4 Volumes), Macmillan Press. (*Information Centre: REF 635 (03) ROY*).

APS compendia – various years. Published by the American Phytopathological Society *(available in library of mycology lab)*

Arnett R.H. (2000) American Insects – a handbook of the insects of America north of Mexico, 2nd edn., Van Nostrand Reinhold, New York, 850pp (*Information Centre: REF 595.7(7)/Arn*).

Baker, J.J. (1972) Report on diseases of cultivated plants in England & Wales for the years 1957-1968. *Technical Bulletin, MAFF* 25, 322pp. *(Mycology Lab)*

Beaton, C. (Ed.) (2006) The Farm Management Handbook 2006/07 – The UK reference for farm business management (27th edn.), SAC, 517pp (*Information Centre: REF 631.1BRA*).

Brookes, G. (2005) European arable crop profit margins 2004/2005, Brookes West, Canterbury, 277pp (*Information Centre: REF 631.1BRO*).

Bosik, J.J. (Ed.) (1997) Common names of insects and related organisms. Entomological Society of America, 232pp. (*Copy in PRA library, Room 02FA06 and older copies in information Centre: REF 03:595.7 ENT*).

Bradbury. J.F. (1986) Guide to Plant Pathogenic Bacteria. CAB International. (02FA03/mycology lab)

Buczacki, S.T., Harris, K.M., Hargreaves, B. (2005). Pests, Diseases and Disorders of Garden Plants. Collins. *(Information Centre: REF 635.2/BUC)*

CABI Arthropod Name Index on CD-Rom (1996). Gives information on synonyms and links to old Review of Applied Entomology volumes (including pre 1973) (*Information Centre: ask at the desk*).

CABI Distribution maps of Quarantine Pests for Europe (1998) Distribution maps of quarantine pests for the European Union and for the European and Mediterranean Plant Protection Organisation, CABI publishing and EPPO (*Lab 02F04*).

CABI Maps No. 1-550, Distribution maps for pests, CABI Wallingford (*Information Centre: Next to Review of Applied Entomology, in journal section*).

Carlile, M.J., Watkinson, S.C., Gooday G.W. (2001) The Fungi 2nd Edition. Elsevier Academic Press. *(Library).*

Cannon, P.F., Hawksworth, D.L., Sherwood-Pike, M.A., (1985). The British Ascomycotina: An Annotated Checklist. Commonwealth Agricultural Bureaux. *(02FA03/mycology lab)*

Chandler, P. (Ed.) (1998) Checklists of Insects of the British Isles (New Series) Part 1 DIPTERA, Handbooks for the Volume 12 Identification of British Insects, Royal Entomological Society, 234pp (*Lab. 02F04*).

CLIMEX – programme which looks at climatic data (1931-1960) from around the world (*available on Alan and Richard's PC's. Currently waiting for an update*).

Davidson, R.H. & Lyon, W.F. (1987) Insect Pests of farm, garden and orchard. 8th Edn. John Wiley, Chichester, 640pp. (*Lab. 02F04 and Information Centre: REF 632.6/.7 DAV*).

De Rougemont, G.M. (1989) A field guide to the crops of Britain and Europe, Collins, London, 367pp. (*Information Centre: REF 581.9(4)/RO*).

Derwent Publications (Eds.) (1990) Thesaurus of Agricultural Organisms: Pests, Weeds & Diseases, Chapman & Hall, London, 2 Volumes. (*Information Centre: REF 03.63 Der*).

Diagnosis database (1996 – present) The Plant Health Diagnosis Database (E-diag) – interception / diagnosis database. (*available on secure pages of CSL Intranet and through the PHIW*).

DOMERO (1988 – present) The PHSI database and recording system for visits and outbreak reports. Prior to this were the interceptions reports, although there is a gap in the records in 1986-87. There are a number of versions of DOMERO, and permission to access information from ALL versions has to be obtained (and carried out by) the *PHSI*.

Ellis, M.B., & Ellis, J.P. (1985) Microfungi on Land Plants. Croom Helm Ltd. *(02FA03/mycology lab)*

EPPO QPE data sheets (1997) – EPPO QPE Book (1997), data sheets on quarantine pests (*Available on T:/PLH/Shared/EPPO QPE book (1997) and also as hard copy, see Smith et al. (1997)*).

EPPO PQR version 5.3.2 (Sept 2014) EPPO Plant Quarantine Data Retrieval System – Updated periodically. Also available for download at: http://www.eppo.org/DATABASES/pqr/pqr.htm

EPPO Reporting Service (Monthly) – EPPO Monthly Reporting Service. *Available online* (see EPPO website). Records from Jan 1998 stored at *T:/Plh/Shared/EPPO RS/. Older records found as paper files PPP 5771, 5771A, 8660 (CL).*

Esser, R.P. (1991) A computer ready check list of the genera and species of phytoparasitic nematodes, including a list of mnemonically coded subject categories. Florida Dept. of Agriculture and Consumer Services, 185pp. (*Information Centre: REF 632.651/Ess*).

Evans, G.O., Sheals, J.G. & Macfarlane, D. (1961) The terrestrial Acari of the British Isles: An introduction to their morphology, biology and classification Volume 1, Introduction and Biology, British Museum (Natural History), London, 220pp. (*Information Centre: REF 595.42*).

Evans, K., Trudgill, D.L.& Webster, J.M. Eds. (1993) Plant Parasitic Nematodes in temperate Agriculture. CAB International, Wallingford, 648pp. (*Sue Hockland has a copy in Room 02F05*)

EU Notifications of findings by NPPOs 1995-2005 – a spreadsheet listing notifications of pests detected as interceptions, and other plant passport infringements, notified to the European Commission by plant health services in Member States. N.B. may be some double counting of an interception as document contains provisional and final notifications (T:/plh/shared/pra/EC notifications 1995-2005.xls).

FAO (1984a) Agroclimaticological data for Africa. Volume I Countries North of the equator, Plant production and Protection Series No. 22, FAO, Rome. (*Information Centre: REF 551.582.2 (5) FOO*).

FAO (1984b) Agroclimaticological data for Africa. Volume II Countries South of the equator, Plant Production and Protection Series No. 22, FAO, Rome. (*Information Centre: REF 551.582.2 (5) FOO*).

FAO (1985) Agroclimaticological data for Latin America and the Caribbean, Plant Production and Protection Series No. 24, FAO, Rome. (*Information Centre: REF 551.582.2 (5) FOO*).

FAO (1987a) Agroclimaticological data for Asia, Volume I Countries A-J, Plant Production and Protection Series No. 25, FAO, Rome. (*Information Centre: REF 551.582.2 (5) FOO*).

FAO (1987b) Agroclimaticological data for Asia, Volume II Countries K-Z, Plant Production and Protection Series No. 25, FAO, Rome. (*Information Centre: REF 551.582.2 (5) FOO*).

Farnworth, J. (1997) Agri Info – Guidelines for world crop and livestock production, John Wiley, Chichester, 576pp. (*Information Centre: REF 31:63/Far*).

Gratwick, M. (Ed.) (1992) Crop pests in the UK – collected MAFF leaflets, Chapman & Hall, London, 490pp. (*Information Centre: 632.7 (410) MIN and Sue Hockland, Room 02F05 and Lab. 02F04*).

Gilbert, P & Hamilton, C.J. (1990) Entomology – A guide to information sources, Mansell, London, 259pp. (*Information Centre: REF 058:595.7/GIL, and older version available in PRA library, Room 02FA06*).

Hill, D.S. (1983) Agricultural Insect Pests of the Tropics and their control, 2nd Edn., Cambridge University Press, London, 746pp. (*Lab 02F04 and older copy in Information Centre: REF 632.9(213)/HIL*).

Hill, D.S. (1987) Agricultural Insect Pests of Temperate Regions and their control, Cambridge University Press, London, 660pp. (*Lab 02F04 and Information Centre: REF 632.9 (213) / HIL).*

Hill, D.S. (1997) The Economic Importance of Insects, Chapman & Hall, London, 395pp. (*Information Centre: REF 632.7 / HIL*).

HMSO (1972) Tables of temperature, relative humidity, precipitation & sunshine for the world, Part 3, Europe and the Azores, HMSO, London. (*Information Centre: REF 551.582.2 Met*).

HMSO (1980) Tables of temperature, relative humidity, precipitation & sunshine for the world, Part 1, North America & Greenland (including Hawaii and Bermuda), HMSO, London. (*Information Centre: REF 551.582.2 Met*).

HMSO (1983) Tables of temperature, relative humidity, precipitation & sunshine for the world, Part 4, Africa, the Atlantic Ocean south of 35ºN and the Indian Ocean, HMSO, London. (*Information Centre REF: 551.582.2 Met*).

Hollis D. (Ed.) (1980) Animal Identification: A reference guide, Volume 3: Insects, John Wiley & Sons, Chichester, 160pp. (*Information Centre: REF 595.7 Hol – may need to ask for help finding this*).

Howes, F.N. (1974) A dictionary of useful and everyday plants and their common names, Cambridge University Press, 290pp. (*Information Centre REF: 03:58 How*).

INFServb "biology" – the old Pest Biology Database from Harpm. List of pests on this held in Alan's office (*available at CSL INFServb "biology" on PC*).

Interception reports (1975-1985) PHSI Interception Records prior to DOMERO. Paper records (*available in Room 02FA07*).

Jeppson, L.R., Keiffer, H.H. & Baker, E.W. (1975) Mites Injurious to Economic Plants, University of California Press, Berkley, 614pp (*Lab 02F04 and Information Centre: 632.7 JEP*).

Kloet G.S. & Hinks W.D. (various years) A check list of British Insects Parts 1 to 5, Royal Entomological Society, London. (*Information Centre: 595.7 Roy*).

Legon, N.W., Henrici, A. (2005). Checklist of the British & Irish Basidiomycota. Kew Gardens. *(02FA03).*

Luc, M., Sikora, R.A. & Bridge, J. Eds. (2005) Plant Parasitic Nematodes in Subtropical and tropical Agriculture. CAB International, Wallingford, 871pp. (*Sue Hockland has a copy, Room 02F05*)

Mabberley, D.J. (1997) The plant book, a portable dictionary of higher plants. 2nd Edition. Cambridge, 857pp. (*Information Centre: 03:58/MAB*).

Maitland Emmet, A. & Heath, J. (1991) The moths and butterflies of Great Britain and Ireland, Volume 7, Part 2, Lasiocampidae – Thyatiridae with Life History Chart of the British Lepidoptera, Harley Books, Colchester, 400pp. (*Richard Baker's personal copy Room 02FA05*; *Information Centre: REF 595.78(410)/EMM*).

Metcalf, R.L. & Metcalf, R.A. (1993) Destructive & Useful Insects, 5th Edn., McGraw-Hill, New York. (*Information Centre: REF 595.7 MET*).

Moore, W.C. (1959) British Parasitic Fungi. Cambridge University Press. *(02FA03/mycology lab/library)*

Nix, J., Hill, P. & Edwards, A. (2006) Farm Management Pocketbook (36th Edn.), Imperial College London, 264pp. (*Information Centre: REF 631.1/NIX*).

Pearce, E.A. & Smith, C.G. (1990) The world weather guide, Hutchinson, London, 480pp. (*Information Centre: REF 551.582.2 Pea*).

PHIW (Ongoing) Plant Health Information Warehouse – *on secure pages of Intranet*.

PHSI IMPS (imports) database (ongoing) – data collated by customs which PHSI have access to. *Available by request to PHSI*.

Preston, C.D., Pearman, D.A. & Dines, T.D. (2002) New atlas of the British and Irish Flora, Oxford University Press, 910pp. (*Information Centre: REF 581.9(41)PRE and also (and more up to date) on CD Rom, downloadable to PC).*

Registered files (PPH and PPP) (Ongoing) Listed on *Intranet under Information Centre, filed in Room 02F09. Also search for titles using keywords on Genservc via "PUTTY".*

Schaeffer & Panizzi (2000) Heteroptera of Economic Importance, CRC Press LLC, 828pp. (*Information centre: REF 595.754/SCH*).

SOCPHIR – Summaries of Overseas Countries Plant Health Import Regulations. Blue files containing by country lists of phytosanitary import regulations, including updates on the legislation. (*Copies throughout PLH, main source with Sam Bishop, Room 02FA03. Also available on: T:\PLH\PLHA\Folders\Eails\Trade\Exports|SOCPHIR\All SOCPHIRS*).

Smith, I.M., Dunez, J., Lelliott, R.A., Phillips, D.H., Archer, S.A. (1988). European Handbook of Plant Diseases. Blackwell Scientific Publications, Oxford.

Smith, I.M., McNamara, D.G., Scott, P.R. & Harris, K.M. (Eds.) (1997) Quarantine Pests for Europe, 2nd Edn., EPPO / CABI, Wallingford, 1425pp. (*Copy in Room 02FA06, also available on t/ph/shared/EPPO QPE book (1997). Older edition (1992) in Information Centre: REF 632 SMI and 632(4) CAB*).

Smith, I.M. & Roy, A.S. (Eds.) (1996) Illustrations of Quarantine Pests for Europe, EPPO / CABI, Wallingford, 241pp (*Information Centre: REF 632(4)/EPP*).

Tomlin, C. (2003) The World Compendium – The Pesticide Manual (13th edn.), BCPC Publications, Hamps., 1344pp. (*Room 02FA07*).

Tutin et al., (1964-1980) Flora Europaea, 5 Volumes, (1964-1980). Also a separate consolidated index. Cambridge University Press. (*Information Centre: REF 581.9 (4) TUT*).

Waller, J.M., Lenne, J.M., Waller., S.J. (2005) Plant Pathologists Pocketbook 3rd Edition. CABI. *(02FA03//library)*

Whitehead, R. (Ed.) (2006) The UK Pesticide Guide, CAB International, BCPC, Cambridge University, 637pp. (*Room 02FA06 and Information Centre: REF 632.95CAB*).

Willmott, S., Gooch, P.S., Siddiqi, M.R. & Franklin, M. Eds. (Various years) Descriptions of plant parasitic nematodes – (Set 1, No 1-15 (1972) to Sey 8, No. 106-120 (1985)). Issued by the Commonwealth Institute of Helminthology. (*See Sue Hockland, Some copies also in Room 02FA07*).

Wood, A.M. (1989) Insects of Economic Importance: a check list of preferred names. CAB International, Wallingford, 150pp. (*Copy in PRA Library, Room 02FA06 and Information Centre: REF 03:595.7 Woo*).

Zeven, A.C. & de Wet, J.M.J (1982) Dictionary of cultivated plants and their regions of diversity, Wageningen, 263pp. (*Information Centre: 03:58 Zev*).

N.B. Once you find a recent information source, you should check its references or bibliography to uncover key or previous references.

Internet Sources Commonly Used During Intelligence Gathering

N.B. When doing web searches for a pest or host don't forget to use common, as well as Latin names.

Searching using keywords on:

Search engines: Webcrawler, Google, Excite, Yahoo, Lycos, Google (Scholar).

Journal abstracts: Web of Knowledge, Ovid, Google (Scholar), Ingentaconnect.

Websites

AQIS - The Australian Quarantine and Inspection Service http://www.daff.gov.au/aqis

Australian Museum Online - http://www.amonline.net.au/

BASIC HORT. STATS. - BASIC HORTICULTURAL STATISTICS, DEFRA (Online). http://statistics.defra.gov.uk/esg/publications/bhs/default.asp

BSBI Atlas – Botanical Society of the British Isles, vascular plant atlas update project. http://www.bsbimaps.org.uk/atlas/

Butterflies and Moths of North America - Occurrence maps, species accounts, checklists and photographs. http://www.butterfliesandmoths.org/

CABI CPC - CABI Crop Protection Compendium (Online). http://www.cabi.org/compendia/cpc/index.htm

CABI FC - CABI Forestry Compendium (Online). http://www.cabi.org/compendia/fc/

The Coleopterist – contains the Checklist of Beetles of the British Isles Coleopterists http://www.coleopterist.org.uk/

CSIRO - CSIRO Entomology. http://www.ento.csiro.au/

Cullen AC and Frey HC, 1999. Probabilistic techniques in exposure assessment. Plenum Press, New York

DEFRA Agricultural Census – data on crop types and land use at various levels. http://farmstats.defra.gov.uk/cs/farmstats_data/DATA/soa_data/repop_query.asp?type=3&disp=nuts1_id%2C+nuts3_id%2C+nuts4_id%2C+soa_id&submit=Go+to+next+step#steps

DIPTERISTSFORUM - Checklists of Insects of the British Isles (New Series). Part 1: Diptera P.J. Chandler, 1998. Handbooks for the Identification of British Insects, 12: 1-234. http://www.dipteristsforum.org.u/

DPVWeb – Descriptions of plant viruses. http://www.dpvweb.net/

EFSA (European Food Safety Authority), (2008). Pest Risk Assessment. Science in support of phytosanitary decision-making in the European Community. EFSA Scientific Colloquium 10.

EFSA (European Food Safety Authority), 2009b. Transparency in Risk Assessment – Guidance of the Scientific Committee on Transparency in the Scientific Aspects of Risk Assessments carried out by EFSA. Part 2: General principles. The EFSA Journal, 1051, 1–22.

EFSA Panel on Plant Health (PLH) (2010); Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA. EFSA Journal 1495: 1-66

EFSA Panel on Plant Health (PLH); Scientific opinion on a quantitative pathway analysis of the likelihood of Tilletia indica M. introduction into EU with importation of US wheat. EFSA Journal 2010; 8(6):1621..

EPPO – European Plant Protection Organisation. http://www.eppo.org/

Farr, D.F., Rossman, A.Y., Palm, M.E., & McCray, E.B. (n.d.) Fungal Databases, Systematic Botany & Mycology Laboratory, ARS, USDA. Retrieved July 24, 2007, from http://nt.ars-grin.gov/fungaldatabases/

FAO Statistics - records from over 210 countries and territories covering statistics on agriculture, nutrition, fisheries, forestry, food aid, land use and population. http://faostat.fao.org/

Fauna Europaea - a database of the scientific names and distribution of all living multicellular European land and fresh-water animals. Names of relevant experts also given. http://www.faunaeur.org/index.php. Is also useful to follow links from this site to other useful online databases and lists.

Flora Europaea – Royal Botanic Garden Edinburgh – on-line search with data extracted from the digital version of Flora Europaea. http://rbg-web2.rbge.org.uk/FE/fe.html

Fowler G, Caton B, Jackson L, Neeley A, Bunce L, Borchert D, McDowell R, 2006. Quantitative pathway initiated pest risk assessment: risks to the Southern United States associated with pine shoot beetle, Tomicus piniperda (Linnaeus), (Coleoptera: Scolytidae), on pine bark nuggets, logs and lumber with bark and stumps from the United States quarantined area. United States Department of Agriculture Animal and Plant Health Inspection Service, Raleigh, NC, USA, June 2006, pp. 96. Available at http://www.aphis.usda.gov/plant_health/plant_pest_info/psb/downloads/southtimberpra.pdf

FNA – Flora of North America. http://hua.huh.harvard.edu/FNA/

Fungal Records Database of Britain and Ireland- http://194.203.77.76/fieldmycology/

FVO – Food and Veterinary Office: Run by the European Commission the FVO have an annual inspections programme, including plant health inspections. Reports can be viewed on http://ec.europa.eu/food/fvo/index_en.htm

ICTVdB - Virus databases online. www.ncbi.nlm.nih.gov/ICTVdb/

Insects and Entomology / Iowa State Entomology Index of Internet Resources – directory and search engine for entomology related resources on the internet. http://www.ent.iastate.edu/list/

International Plant Names Index (IPNI) – collaboration between Kew Gardens, Harvard University Herbaria and the Australian National Herbarium. http://www.ipni.org/index.html

IPPC – International Phytosanitary Portal https://www.ippc.int/IPP/En/default.jsp

Leafminers - British Leafminers http://www.leafmines.co.uk/

Lepidoptera and some other life forms - http://www.funet.fi/pub/sci/bio/life/intro.html

Lepindex – The Global Lepidoptera Names Index http://www.nhm.ac.uk/research-curation/projects/lepindex/

Luciddcentral – University of Queensland, entomological keys. http://www.lucidcentral.org/keys/

MET Office: Climate averages - http://www.metoffice.gov.uk/climate/uk/averages/index.html

NAPPO – North American Plant Protection Organisation. http://www.nappo.org

NAPIS – National Agricultural Pest Information System (US). http://ceris.purdue.edu/napis/

National Biodiversity Network's Species Dictionary – Natural History Museum, standard reference for names of organisms found in the United Kingdom. http://nbn.nhm.ac.uk/nhm/

NCBI Entrez Taxonomy Homepage - www.ncbi.nlm.nih.gov/sites/entrez?db=Taxonomy

New Disease Reports - http://www.bspp.org.uk/ndr/

Pest Fruit Flies of the World – Guide to Diptera: Tephritidae. http://delta-intkey.com/ffl/www/_wintro.htm

Peterson GL, Whitaker TB, Stefanski RJ, Podleckis EV, Phillips JC, Wu JS and Martinez WH, 2009. A risk assessment model for importation of United States milling wheat containing Tilletia controversa. Plant disease, 93: 560-573.

Plant Pathology Internet Guide Book - http://www.pk.uni-bonn.de/ppigb/ppigb.htm

Plant Disease Notes - http://www.apsnet.org/pd/

Pro Med Mail - http://www.promedmail.org/

RHS Plant Finder: online links to sections of the book - http://www.rhs.org.uk/rhsplantfinder/plantfinder.asp

Roberts RG, Hale CN, van der Zwet T., Miller CE and Redlin SC, 1998. The potential for spread of Erwinia amylovara and fire blight via commercial apple fruit: a critical review and risk assessment. Crop protection 17: 19-28.

ScaleNet – all about scale insects http://www.sel.barc.usda.gov/scalenet/query.htm

Stansbury CD, McKirdy SJ, Diggle AJ and Riley IT, 2002. Modeling the risk of entry, establishment, spread, containment, and economic impact of Tilletia indica, the cause of Karnal bunt of wheat, using an Australian context. Phytopathology 92:321-331.

Systematic Entomology Laboratory – United States Department of Agriculture – Insect and Mite Identification Service. Includes links to many useful sites. http://www.ars.usda.gov/Main/site_main.htm?modecode=12-75-41-00

US APHIS Plant Health – US Department of Agriculture: Animal and Plant Health Inspection Service http://www.aphis.usda.gov/plant_health/index.shtml

Whitefly Taxonomic and Ecological Website - http://www.fsca-dpi.org/homoptera_hemiptera/Whitefly/whitefly_catalog.htm

World Factbook – (A – Z Countries) CIA. https://www.cia.gov/library/publications/the-world-factbook/geos/nz.html

World Meteorological Organization (WMO) - http://www.wmo.int/pages/index_en.html