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SLU Risk Assessment of Plant Pests

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Potential establishment of the priority pest *Rhagoletis pomonella* in Sweden

Background and terms of reference

The European Commission has established a list of 20 priority pests (Commission Delegated regulation (EU) 2019/1702). The pests have been selected among the Union quarantine pests as the pests for which the potential economic, environmental and social impact is assessed to be the most severe in the EU.

For each priority pest Member States shall carry out annual surveys (article 24 in EU regulation 2016/2031). However, the regulation further states that:

"The surveys shall not be required to be carried out for pests for which it is unequivocally concluded that they cannot become established or spread in the Member State concerned due to its ecoclimatic conditions or to the absence of the host species."

For some of the priority pests it is currently uncertain whether the ecoclimatic conditions or host availability in Sweden allow their establishment in whole or part of the country.

The Swedish Board of Agriculture has requested SLU Risk Assessment of Plant Pests to assess whether certain priority pests are able to establish in Sweden and further, when relevant, identify the area of potential establishment. This report provides the assessment of the potential establishment of *Rhagoletis pomonella* (EPPO code: RHAGPO).

Short description of *Rhagoletis pomonella*

Rhagoletis pomonella (apple maggot) is a species of fruit fly, which has a major impact on apple production in the USA (Kumar et al. 2016). The current geographical distribution is limited to North America and ranges from Mexico to Canada (EPPO, 2020). There are two races defined, one with a preference for hawthorn (*Crataegus* spp.) and one race which has developed after the introduction of *Malus domestica* into the area where the pest was established, and this race also has a preference for this plant host (EFSA, 2019a). In addition, other plant species of the family *Rosaceae* has also been reported as hosts (EFSA, 2019a).

In short the life cycle is as follows; oviposition occurs under the skin of fruits from susceptible host plants, the larvae develop within the fruits and pupation occurs in the soil beneath the host plants (Smith et al. 1996). Normally *R. pomonella* overwinters as a pupa in the soil and one generation develops per year, although both longer and shorter development times have also been observed (Smith et al. 1996).

Adults of *R. pomonella* can fly more than 1 km in one day in the absence of susceptible host fruits (CABI, 2020).

Ecoclimatic conditions

In a pest report for the species by EFSA (2019a) the potential range of establishment of *R. pomonella* in the EU was analyzed using the climate niche model CLIMEX (Sutherst and Maywald, 1985). The analysis was based on the pest specific parameter values for CLIMEX published by Kumar et al. (2016) and using climate data for the period 1998-2017 from JRC (EFSA, 2019b). EFSA (2019a) concluded that large areas of Scandinavia were climatically unsuitable for establishment of *R. pomonella*.

We further estimated the area of potential establishment at national level using the Ecoclimatic Index (EI) of CLIMEX generated by EFSA (2019a). The data were provided for further exploration as an additional output of EFSAs work via the interactive site https://arcg.is/05i5qX. The EI values were extracted and depicted on a map of Sweden using QGIS (QGIS Development Team, 2020; Figure 1). The EI values were presented according to Kumar et al. (2016), as the following arbitrary EI classes; an EI = 0 indicate unsuitable locations, an EI = 1-3 indicate marginally suitable locations, an EI = 4-10 indicate moderately suitable locations, while an EI = 11-25 indicate favourable locations and an EI > 25 indicate highly favourable locations.

The resulting map shows that the EI in the northern parts of Sweden is equal to 0 (Figure 1). This indicates that *R. pomonella* is unable to persist in these locations and that the climatic conditions are unsuitable for establishment of the species (Kriticos et al. 2015). The southern parts of Sweden have an EI ranging from marginal to highly favourable (EI between 1-3 and > 25) for establishment.

The position of the border between unsuitable and suitable areas should be interpreted with care. In the article by Kumar et al. (2016) it is stated that some observations of the pest in Canada were not correctly predicted by the model and thus the model may be an underestimation of the potential distribution. Further, *R. pomonella* may be expanding its range considering that the pest is spreading to new areas (Parsons & Sinclair, 2018).

Kumar et al. (2016) also analysed the potential establishment globally using the species distribution model MaxEnt. The results for Sweden were similar to those obtained from the model CLIMEX in terms of the area considered to be unsuitable which provides further support for that the climate in Sweden is suitable for the pest. The MaxEnt model was however more conservative than CLIMEX within the area not considered to be unsuitable, e.g. according to the MaxEnt model the probability of establishment was only rated as low-medium in areas depicted as highly favorable using the CLIMEX model. It should be noted that these two models use

different approaches, including different sets of bioclimatic data. In addition, the MaxEnt model also included the climate suitability of apple species in the model (Kumar et al. 2016).

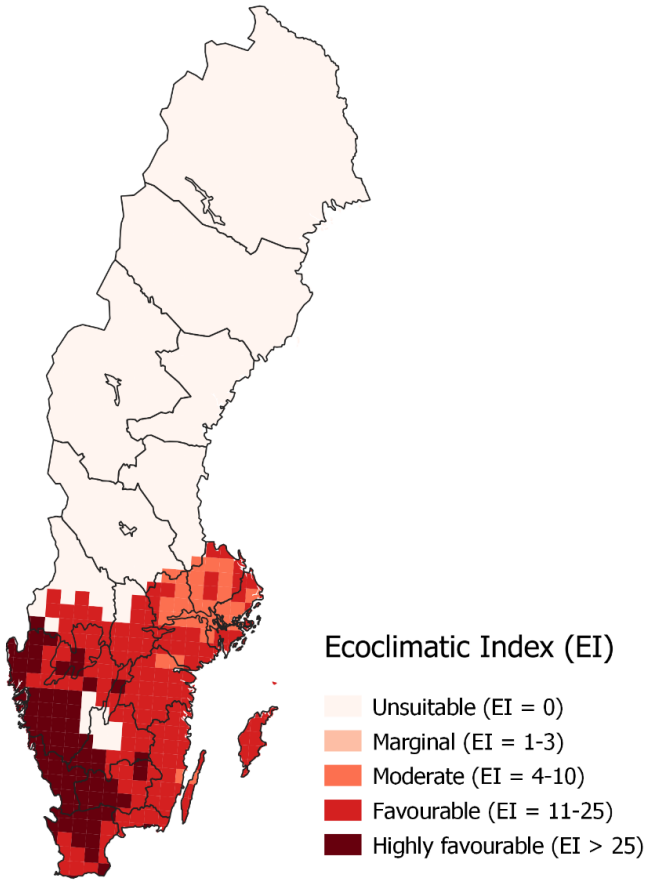

Figure 1. *Ecoclimatic Index (EI) from the bioclimate model CLIMEX for* R. pomonella *displayed for Sweden. The EI values are from EFSA (2019) provided as an additional output at https://arcg.is/05i5qX. The map of the counties in Sweden is from SCB (2020).*

That the climate in Sweden is suitable for *R. pomonella* is also supported by observations from North America that confirm that the pest is present in the Köppen-Geiger climate zone Dfb which is also found in the southern part of Sweden (Kumar et al. 2016, Beck et al. 2018; Figure 2a). The pest is also reported to be distributed across Canada (e.g. Parsons & Sinclair, 2018; Canadian Food Inspection, 2019). It is, however, questionable whether the pest is also established in areas with a Köppen-Geiger climate zone corresponding to that currently found in the northern part of Sweden (Dfc), *i.e.* approximately north of *Limes norrlandicus* (Appendix 1).

It should be noted that climate change is projected to shift the distribution of the Köppen-Geiger climate zones northwards (Beck et al. 2018) and that figure 2a may not reflect the recent increase in temperatures since it is based on the average climate during the time period 1980-2016. In a future scenario (based on RCP 8.5) for the time period 2071-2100 the climate zone

Dfb is expected to cover most of the northern parts of Sweden, while the southern parts are represented by the climate zone Cfb (Beck et al. 2018; Figure 2b).

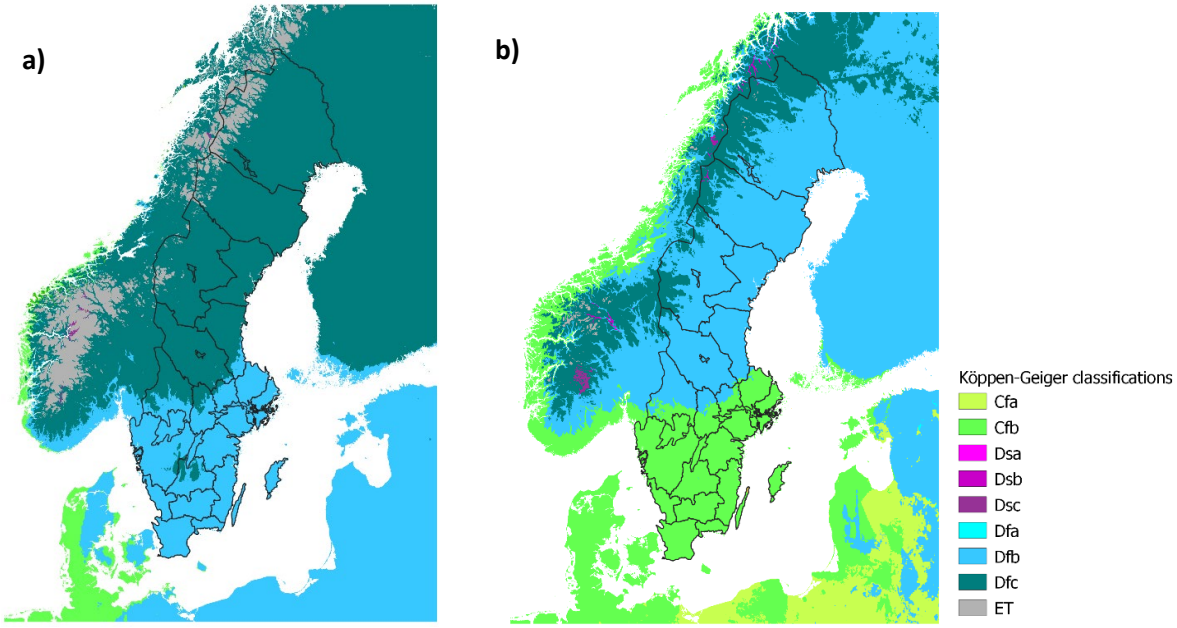

Figure 2. *Köppen-Geiger climate classifications in Sweden and surrounding areas based on a) the climate during the time period 1980-2016 and b) the predicted climate according to scenario RCP 8.5 for the time period 2071-2100 (modified maps from Beck et al. 2016; www.gloh2o.org/koppen; available under the CC BY-NC 4.0 license). The map of the counties in Sweden is from SCB (2020).*

Finally, in agreement with previous studies also current modelling work at ETH in Switzerland indicate that *R. pomonella* would be able to establish in Sweden (M. Grünig, pers. comm., 15 April 2020). This work includes both "physiological models", which are based on measured development thresholds and species distribution modelling work based on occurrence data and the following parameters: minimum temperature of the coldest month, growing degree-days above 5°C, annual precipitation and precipitation seasonality.

Presence and distribution of hosts

Susceptible hosts are widely distributed in Sweden. *Malus domestica* and species of *Prunus* and *Pyrus* are found in production sites and are very common in private gardens. Also other species of genera such as *Amelanchier*, *Aronia*, *Contoneaster, Crataegus* and *Rosa* are common plants in gardens and parks etc. The two latter as well as *Sorbus aucuparia* and *Prunus avium* are also found in the wider environment. At least one of the hosts have a distribution that covers the whole of Sweden, e.g. *Sorbus aucuparia* (Räty et al. 2016). Since, adults of *R. pomonella* can search for susceptible host fruits over large distances (>1 km per day; CABI, 2020) the distribution of hosts is not expected to restrict the potential establishment of *R. pomonella* in Sweden.

Conclusion

Based on the information presented above our assessment is that *Rhagoletis pomonella* would be able to establish in Sweden. However, the current climatic conditions in the northern parts of the country is assessed to be unsuitable for the species and thus it is recommended that surveys should be directed towards the southern parts of the country. Further, the results indicate that the climate may be more suitable towards the western part of this region. This information may be used, together with other information, for developing a "Risk-based survey".

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Authors

This report was prepared by SLU Risk Assessment of Plant Pests at the Swedish University of Agricultural Sciences:

Johanna Boberg, Dept. of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences, PO Box 7026, SE-750 07 Uppsala, Sweden. Visiting address: Almas allé 5, E-mail: Johanna.Boberg@slu.se

Niklas Björklund, Dept. of Ecology, Swedish University of Agricultural Sciences, P.O. Box 7044, S-750 07 Uppsala, Sweden. Visiting address: Ullsväg 16, E-mail: Niklas.Bjorklund@slu.se

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Appendix 1. Distribution of *Rhagoletis pomonella* in Canada

Rhagoletis pomonella has been reported in all southern provinces in Canada (Parson and Sinclair, 2018; Canadian Food Inspection, 2019). In North America, a few major apple growing areas in British Columbia are the only ones without the pest (Canadian Food Inspection, 2019). Many records are found in the Köppen-Geiger climate zone Dfb (corresponding to southern Sweden). One record appear to be located in the colder climate zone Dfc, but whether the species is established in the location is not known (Table 1).

Table 1. Sources consulted for the distribution of *Rhagoletis pomonella* in different provinces of Canada.

Records of *Rhagoletis pomonella*	**Reference**
Rhagoletis pomonella is reported as present across the southern provinces in Canada; in British Columbia (partly), Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, Prince Edwards Island and Nova Scotia. Specifically *Rhagoletis pomonella* was reported from the Lower Mainland, Fraser Valley, and Vancouver Island (BC) in 2006, Edmonton (AL) in 2006 and Prince George (BC) in 2013. No specific locations were provided.	Canadian Food Inspection, 2019
In British Columbia *Rhagoletis pomonella* is found on Vancouver Island and the following districts: Mount Waddington, Powell River, Sunshine Coast, Greater Vancouver, Fraser Valley (except Fraser Valley A) and Fraser-Fort George. Single specimens has also been trapped twice in Kelowna in 2015 and 2016, but no further observations has been made. The regions are climatically very heterogeneous and the exact distribution on a smaller geographical scale is not clear.	M. Marcotte, pers. comm. Canadian Food Inspections Agency, 26 March 2020; NAPPO, 2020
Records from British Columbia, Alberta, Manitoba, Ontario, Quebec, New Brunswick, Prince Edwards Island and Nova Scotia.	Kumar et al. 2016

Apple maggot population reported from the Edmonton area, inside as well as outside the city.	P. McAllister, pers. comm. Canadian Food Inspection Agency, 30 March 2020; CABI, 2019 (citing other sources).
Multiple records in the southern parts of Manitoba, south-eastern part of Ontario, Quebec, New Brunswick and Nova Scotia.	Foote et al. 1993
Records from five sites close to Clarensville, Newfoundland	Parsons and Sinclair, 2018
Records from Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia. One record from central Saskatchewan (location Prince Albert NP, Sturgeon crossing) is located in Köppen-Geiger zone Dfc. It is unclear whether the sampled specimen represents a local population. It should be noted that it was found only 22 km away from the closest area with Köppen-Geiger climate zone Dfb.	GBIF.org (3 April 2020) GBIF Occurrence Download [Records were downloaded and mapped on the Köppen-Geiger climate zones according to Beck et al. (2018) using qGIS]
Records from Agriculture Canada Experimental orchard, Frelighsburg, Quebec.	Belanger et al 1985; Bostanian and Coulombe, 1986
Records from Vineland, Ontario.	Hagley and Chiba, 1980
Records from orchards in Ontario, Quebec and Nova Scotia. No specific locations were provided.	Neilson et al. 1976
Records from Kentville and Parrsboro in Nova Scotia	Smith and Bush, 1997
Records from Guelph in Ontario	Laing and Heraty, 1984

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