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SLU Risk Assessment of Plant Pests

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Colorado potato beetle

An analysis to support surveillance of the protected zone in Sweden

Postage stamp from Romania depicting a flying Colorado potato beetle (Wikimedia commons)

Authors

This report was prepared by:

SLU Risk Assessment of Plant Pests, Swedish University of Agricultural Sciences
Webpage: www.slu.se/risk-assessment

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

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

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Background

The Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (EPPO code: LPTNDE), is a European Union (EU) protected zone quarantine pest in certain member states. The Swedish protected zone currently covers five counties in the southern part of the country, i.e. Blekinge, Gotland, Halland, Kalmar and Skåne (Fig. 1A; Annex III of (EU) 2019/2072[1]). However, a recent analysis indicates that the area likely to be suitable for the establishment of the CPB extends much further north than the current protected zone (Björklund et al. 2024).

Commission delegated regulation ((EU) 2022/2404[2]) details the rules for surveys of protected zone quarantine pests. This regulation requires that a stratified survey design should be employed where the member states either create a buffer zone around the protected zone or if that is not possible, an inner band within the protected zone. In Sweden the current protected zone borders the sea and the alternative with an inner band will therefore be used. In contrast to a buffer zone an inner band stretches inwards from the border of a protected zone. In other words, it is as an area in a protected zone surrounding the protected zone on the inner side along its outer border. Surveys in the inner band should be conducted more intensively than in the rest of the protected zone.

SLU Risk assessment of plant pests was requested by the Swedish Board of Agriculture to provide an estimate of a suitable width of an "inner band" for the CPB within an area identified to be suitable for the establishment of the beetle according to the assessment by Björklund et al. (2024). Further, the risk varies along the inner band and therefore the high-risk part of the inner band was also determined since the surveys should be risk-based[2].

Factors included in the assessment

A previous assessment indicates that the climate is suitable for the CPB in a large part of southern Sweden and furthermore that there are enough hosts for the beetle to establish there (Björklund et al. 2024). The conditions in that part of the country were therefore assessed as likely to be suitable for establishment of the CPB (Fig. 1A) and this is the area considered for the assessment of the suitable width and extent of the inner band.

[1] Annex III of (EU) 2019/2072, Official Journal of the European Union, L 319, 1-279 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R2072
[2] Commission delegated regulation ((EU) 2022/2404). Official Journal of the European Union, L 317, 42-53. Available from https://eur-lex.europa.eu/eli/reg_del/2022/2404

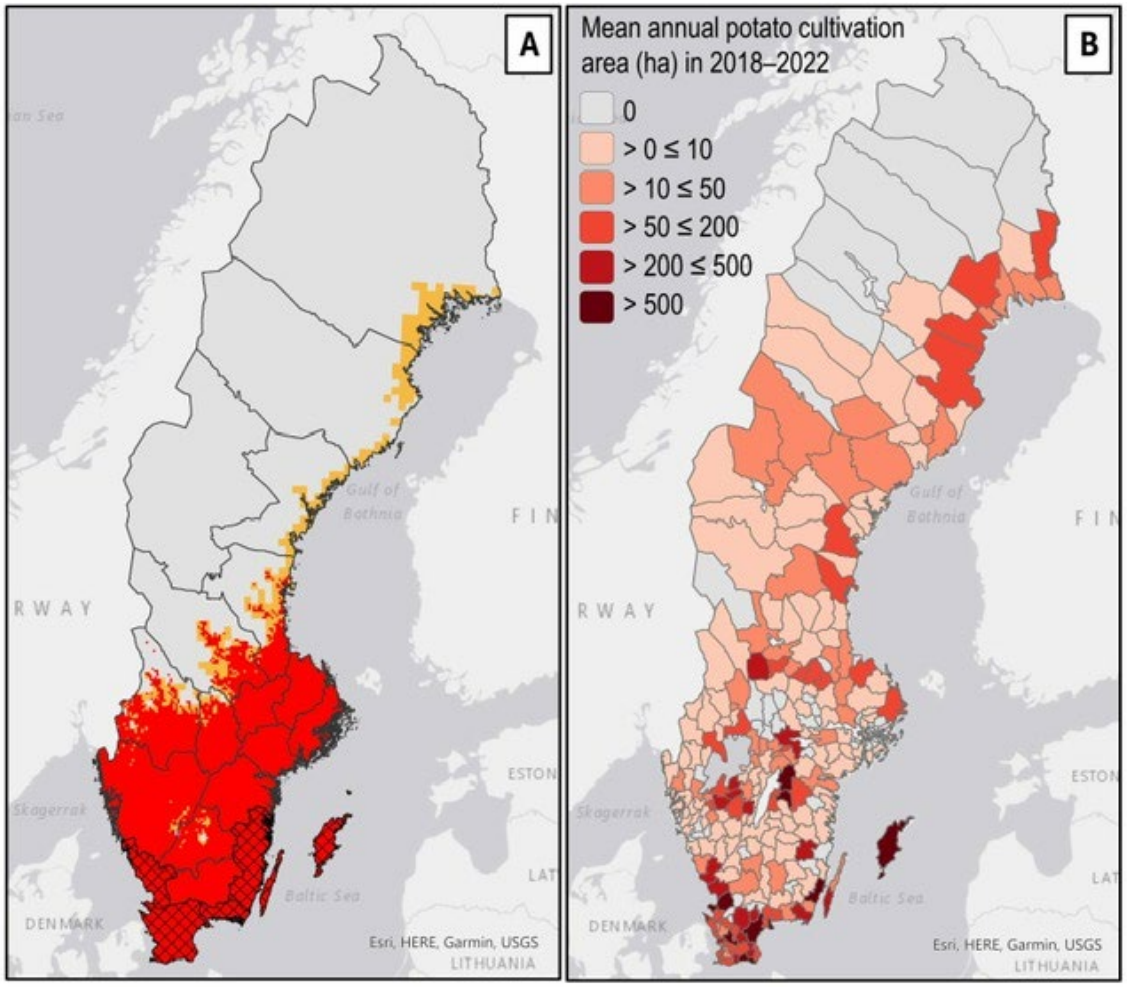

Figure 1. (A) Map showing areas likely to be suitable for the establishment of the Colorado potato beetle (CPB). Red shading indicates areas likely to be suitable for establishment in the recent climate (2003–2022), while orange shading indicates the additional areas likely to be suitable for establishment in a future climate (2031–2050). The geographic subdivisions refer to the counties of Sweden (Sveriges län). Crosshatched pattern denotes EU protected zones for the CPB, i.e., Blekinge, Gotland, Halland, Kalmar and Skåne. **(B)** Mean annual potato cultivation area (ha) in the Swedish municipalities in 2018–2022 (Swedish Board of Agriculture 2022). Note that the category 0 also includes the municipalities for which information was not available. The borders of the municipalities were sourced from SCB (2021). Both maps were adapted from Björklund et al. (2024).

Sweden is situated on the Scandinavian Peninsula with no land border with any country where the CPB is established. Despite this, the CPB has managed to reach Sweden through natural spread across the Baltic Sea on multiple occasions. While the beetle's flying ability is limited, it can travel considerable distances aided by strong winds (Wiktelius 1985). Such long-range dispersal occurred at a large scale in 1972 and 1983, when beetles arrived in Sweden from countries south of the Baltic Sea (Gränsbo 1980; Wiktelius 1985). In both these invasions, many beetles ended up in the sea and some of them drifted in the surface current to the Swedish coast from where they invaded nearby potato fields. Still, some beetles were probably airborne all the way to the fields.

EFSA (2023) suggests that surveillance efforts of the CPB should focus on activities and locations associated with previous interceptions and outbreaks. Accordingly, the current analysis is based on geographic information of previous findings of CPB. Further, EFSA (2023) points out that for the CPB "The most relevant risk factor does not relate to an increased probability of introduction of the pest but to an increased probability of its establishment". Accordingly, our analysis is based on risk factors related to the likelihood of finding the CPB in potato fields, where the likelihood of establishment is higher than in environments with less suitable or no hosts. We therefore consider that the data from the outbreaks in 1972 and 1983 provide the relevant information needed to guide the design of risk-based surveys in the context of an inner band.

Since the purpose of the inner band is to detect natural spread from neighboring areas, human-assisted spread, e.g., via trade of potato, is not considered. It may however be noted that the proportion of beetles that have entered Sweden through trade is marginal compared to the proportion that have entered through natural spread, e.g. there are only five trade related interceptions of CPB reported from Sweden (EFSA 2020).

Analyzing data from past invasions

A two-step procedure was used to identify areas where surveillance efforts for the CPB should be focused. The first step was to determine the high-risk part of the inner band, while the second step was to determine its width.

Determining the high-risk part of the inner band

During the mass invasion in 1972, large numbers of beetles were found mostly in the counties Skåne and Blekinge but also in Halland (up north to the city Falkenberg) and Kalmar (to the city Västervik) as well as on the island Öland (Johansson 1973) whereas during the invasion in 1983 most beetles ended up in Halland (Wiktelius 1985) (Fig. 2).

We assess that the coastal area between Göteborg on the west coast and Västervik on the east coast (including Öland) constitutes a high-risk part of an inner band. The reasons for this assessment are;

(1) The two previous invasions show that there is a higher likelihood that wind transported beetles, from surrounding countries where the pest is present, end up at the coastline between Falkenberg and Västervik (Gränsbo 1980; Wiktelius 1985). In addition, the coastline up to Göteborg is included due to the potential spread from Denmark where the pest is now reported relatively frequently (see Björklund et al. (2024) for a review of the current situation there and EPPO (2024) for its pest status).
(2) That area includes the warmest parts of Sweden (Appendix 2), and a warmer climate is expected to be more suitable for the establishment of the CPB (e.g. EFSA 2023).
(3) The density of suitable hosts is relatively high in that area, which increases the likelihood of establishment of the CPB (Fig. 1B).

We suggest that surveys should not focus on the remainder of the inner band since geographic isolation could be considered adequate to prevent introductions there (assuming that the current protected zone is expanded to cover the whole area where the climate is presently suitable for the CPB, see Björklund et al. (2024)). This suggestion is supported by:

(1) Data from two previous invasions (see above).
(2) That there is no CPB population in Norway that can migrate over the border to Sweden.
(3) That there is no CPB population that can migrate to the protected zone from the more northern part of Sweden (where the climate also has been assessed to be unsuitable for establishment of the CPB (Björklund et al. 2024)).

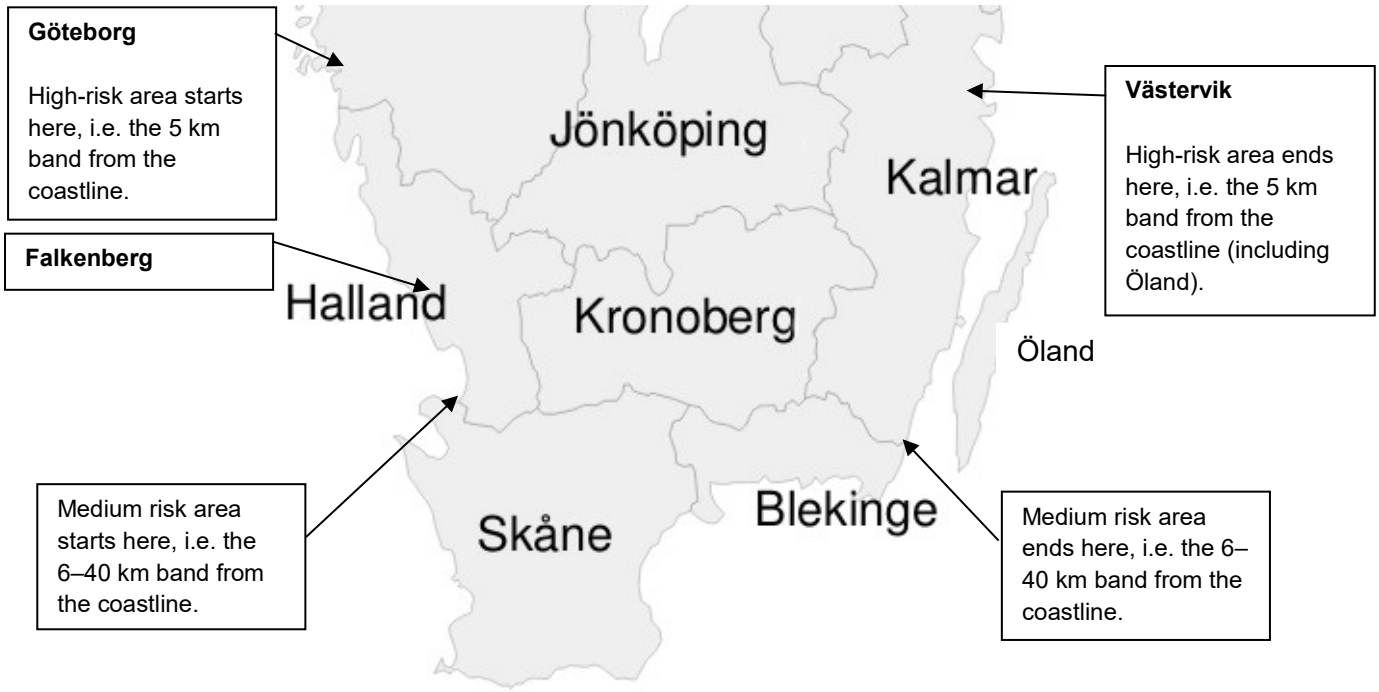

Figure 2. Map with counties (from Wikimedia Commons / CC-BY-SA-3.0 ©Svédország megyéi), and other places mentioned in the text.

Determining the width of the inner band

Inventory data with geographic information of infested potato fields is available from the CPB invasion that started in 1972 and ended in 1977. An inventory conducted in 1972 showed that approximately two thousand potato fields, including home gardens (almost 25%), were infested (Johansson 1973; Gränsbo, 1980). The number of infested fields decreased rapidly over the following years (Fig. 4), as did the total infested area. In 1972, about five thousand hectares were infested, but by 1974 it had been reduced to approximately two hundred hectares and was further reduced to just one hectare by 1977 (Gränsbo 1980). No information was provided about population densities or how large parts of the fields that were infested. Here we determine the

approximate distances of the infested potato fields from the coastline based on information extracted from a map provided in Gränsbo (1980).

Our analysis shows that the number of infested fields in 1972 decreased exponentially with increasing distance from the coastline (Fig. 3). The number of infested fields was more than twice as high within the first 5 km band from the coastline compared to the next 5 km band further inland, and this area is therefore considered the area with the highest likelihood of infestation.

While we recommend that survey activities should be focused in the high-risk area of the 5 km wide inner band we also suggest that the surveillance should include a second layer of the inner band constituting a medium risk area. The reason is that an inner band including the first 5 km from the coastline only includes 40% of the infested fields (Fig. 3). Since more than 95% of the infested fields were within 40 km from the coastline (Fig. 4), we suggest that a medium risk area, consisting of an area between 6–40 km from the coastline could be used. This second layer of the inner band is suggested to be restricted to the counties Skåne and Blekinge since most of the infested potato fields inland were located there, and since the beetles persisted longest there after the 1972 invasion (Fig. 2; Gränsbo 1980). In practice, the second layer of the inner band could be considered to cover the entire area of Skåne and Blekinge. Information about the relative risk in different areas, which may support the development of a survey design, is provided in Appendix 3.

The distribution of infested potato fields described above is based on data from the year of the invasion. However, data from inventories conducted during the years following the invasion, mainly representing locations where the CPB managed to remain a population, show that if anything there is a tendency that an even higher proportion of the infested fields are located close to the coastline (Fig. 4).

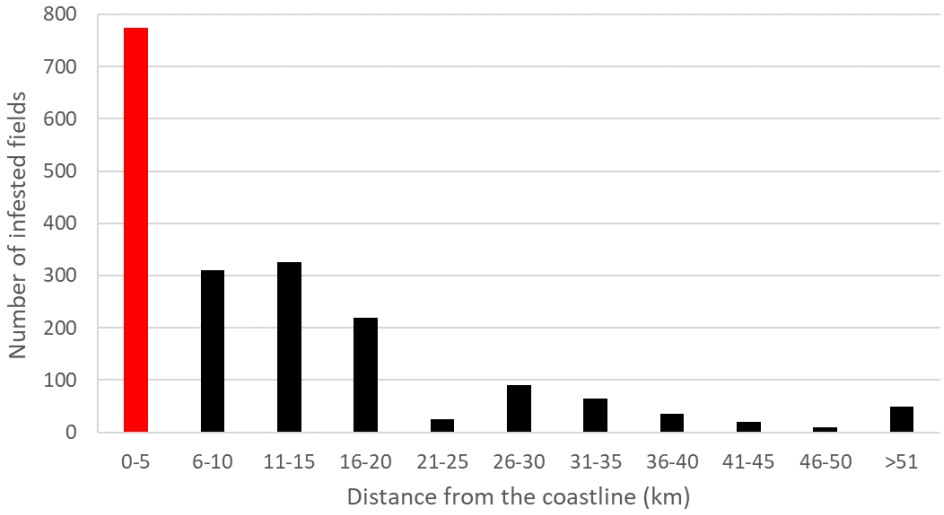

Figure 3. Number of fields infested with the Colorado potato beetle on the mainland at different distances from the coast based on data from the inventory conducted in 1972. Note that the number of infested fields are much higher within the distance range denoted by the red bar compared to other distance ranges. The data was extracted from Fig. 2 in Gränsbo (1980).

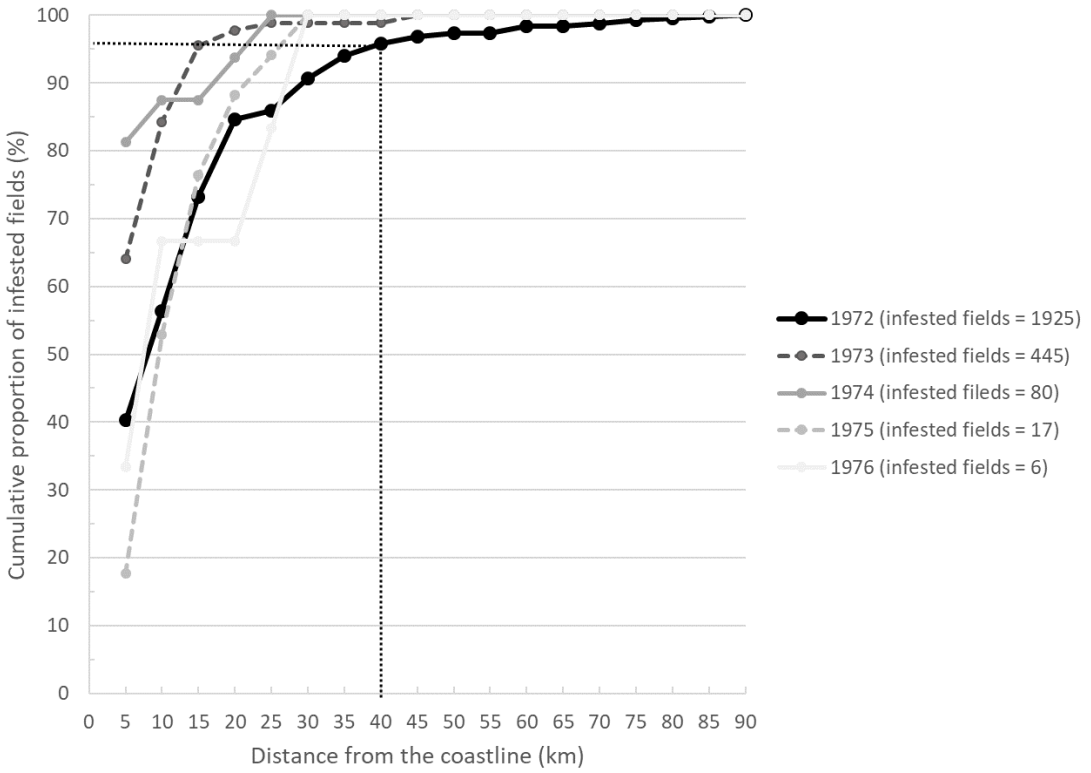

Figure 4. Cumulative proportion of fields infested with the Colorado potato beetle at different distances from the coastline after the large invasion in 1972. Data are shown separately for each year of inventories. Note that the pattern for the last years are uncertain due to the low number of fields that were infested. The dotted line indicates that more than 95% of the infested fields were within 40 km from the coastline.

Uncertainties

It should be noted that the geographic information of the infested potato fields, which was extracted from Gränsbo (1980), is not exact. Each dot on the map represents five infested fields and the resolution of the map was very low.

Observations from more northern locations and from Öland were also mentioned by Gränsbo (1980), but it is not known whether these were from potato fields or if they were found in other places. These observations were therefore only included in our analysis determining the high-risk part of the inner band and not when assessing the width of the high-risk part of the inner band or the medium risk area.

The data used in our analysis only represents information from two invasions, however, the majority of other observations of CPB in Sweden have also been made close to the coastline (Appendix 1). Further, this pattern has also been observed in other countries that are separated by a sea from areas where the CPB is established, e.g., in Denmark and the island of Jersey (Thomas and Wood 1980; Brokenshire et al. 2012; Naturbasen 2023). It is believed that this

pattern is, at least partly, driven by the large numbers of beetles that end up in the sea and drift in surface currents toward the coast. In 1972 for instance, approximately 300 000 beetles were collected along the shores of Sweden in just a two-week period (Gränsbo 1980). Survivors could then invade nearby potato fields (Gränsbo 1980; Wiktelius 1985).

Conclusion

We assess that the coastline between Göteborg on the west coast and Västervik on the east coast (including Öland) should be considered to be a high-risk area. The inner band where inventories should be conducted more intensively is suggested to consist of potato fields as close as possible to the coastline, e.g. using an inner band with a width of 5 km. Further, the use of a second layer of the inner band stretching between 6 and 40 km from the coastline, constituting a medium risk area, is suggested to be included in Skåne and Blekinge.

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Appendix 1. Observations of the Colorado potato beetle in Sweden

Table A1. Observations of the Colorado potato beetle in Sweden*

Year	Description	Numbers	Reference
1876	Custom	3	Ahlberg 1937
1965-70	Mostly along the coast	Occasional	Gränsbo 1980
1971	Mostly along the coast	20 places	Gränsbo 1980
1972-77	Mostly along the coast	Mass invasion	Gränsbo 1980
1983	Mostly along the coast	Mass invasion	Wiktelius 1985; GBIF 2023
2000	Collection	1	SLU 2023
2004	Grocery store	1	SLU 2023
2017	Harbor	1	SLU 2023; EPPO 2024
2021	Potato field	On a few plants	Swedish Board of Agriculture 2024; EPPO 2024

* According to EFSA (2020) there were also 5 interceptions reported from Sweden.

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Appendix 2. Growing degrees days in different parts of Sweden

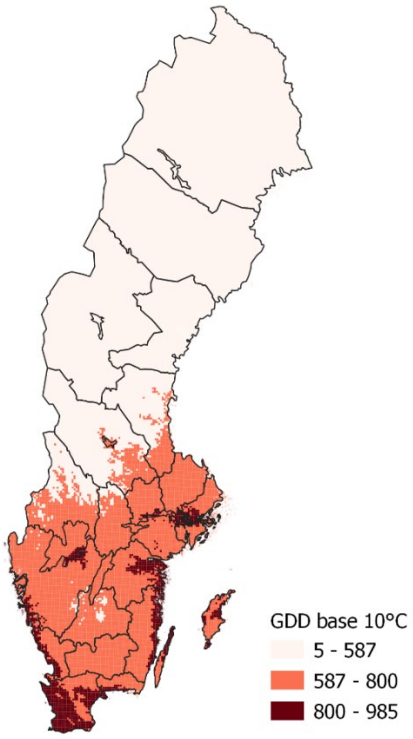

Figure 1. Mean annual growing degree days above 10°C calculated from daily air temperature data from 2003-2022 at a resolution of 4 x 4 km (SMHI 2023a) using method 1 by McMaster and Wilhelm (1997). The geographic subdivisions refer to the counties of Sweden (Sveriges län) according to SCB (2021). The coloured areas represent areas where the summer temperatures enable the development of one complete generation, i.e. where the GDD requirement of 587 is met (Björklund et al. 2024). The range between >800 GDD to the maximum, i.e. 985 GDD, was chosen to depict the areas with the highest accumulated temperatures.

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Appendix 3. Relative risk in different areas

The information and analysis presented in this report can also be used to define a risk factor to support the development of a survey design (EFSA et al. 2023). The probability of infestation differs between the two layers of the inner band and the rest of Sweden where the pest can establish. Thus, the relative risk was calculated for;

(1) The high-risk area. This area extends 5 km inland from the shore, spanning between Göteborg on the west coast and Västervik on the east coast. It also includes Öland.

(2) The medium-risk area. This area extends from 6 to 40 km inland from the coastline and is confined to the counties of Skåne and Blekinge. This second layer of the inner band could be considered to encompass the entire area of Skåne and Blekinge.

(3) The baseline area. This area consists of the rest of Sweden where the climate is currently suitable for the CPB (Fig. 1A).

Estimations of the relative risk ratios were calculated using two different approaches. The first estimation is based solely on empirical data of the number of infested fields per km^2. This estimate is thus influenced by both differences between the areas with regard to the presence of beetles and the presence of potato fields but provides a good direct overall estimation of the relative risk per unit area of land. **The relative risk ratios, *per unit of land area*, were approximately 1:65:129 for the baseline, medium, and high-risk areas, respectively (Table 1).**

Sampling of CPB is, however, usually not conducted at a per unit area of land level, but rather at the level of individual potato fields. Thus, we also calculated a rough estimation considering the area cultivated with potato in the high-risk, medium-risk, and baseline areas (Table 1). We here assume the same number of hectares of potato cultivated per square kilometre in the high-risk area as in the medium-risk area. **The relative risk ratios, *per hectare of potato*, were approximately 1:4:14 for the baseline, medium, and high-risk areas, respectively (Table 1).**

Table 1. The relative risk per unit of land area and per hectare of potato for areas with different risk levels. The data on infested fields were obtained from an inventory conducted in 1972 after a large invasion (Gränsbo 1980), and data on the areas cultivated with potato were obtained from the Swedish Board of Agriculture (2022).

Risk factor level	Number of infested fields	Area (km²)	Number of infested fields per km²	Relative risk per unit of land area	Area cultivated with potato (km²)	Number of infested fields per km² potato	Relative risk per ha potato
High	775[a]	4 275[d]	0.18	129	24.48[g]	31.66	14
Medium	965[b]	11 494[e]	0.084	65	106.93[h]	9.02	4
Baseline	185[c]	130 000[f]	0.0014	1	83.24[i]	2.22	1

[a] See Fig. 3.

[b] The number of infested fields from 6 to 40 km inland from the coastline, i.e. 1070 fields (Fig. 3), minus the number of infested fields at this distance range from outside of Skåne and Blekinge, i.e., 105 fields (data directly from a map in Gränsbo (1980)).

[c] The total number of infested field on the mainland, i.e., 1925 fields (Fig. 3) minus those in high- and medium-risk areas.

[d] The coastline distance between Göteborg on the west coast and Västervik on the east coast is approximately 855 kilometres when measured in a relatively straight line (Table 2). Thus, the area that extends 5 km inland from the coastline is approximately 855 km × 5 km = 4 275 km^2.

[e] The medium risk area constitutes the total land area of the counties of Skåne and Blekinge, i.e. 13 894 km^2 minus the high-risk area in those counties, i.e., 2400 km^2.

[f] Rough estimation of the total potential area of establishment in Sweden based on the recent climate from Figure 1A minus the area of the high- and medium-risk areas.

[g] The area of potato in the band that extends 5 km inland from the shore (see Table 2 for the calculations).

[h] The total area of potato in Skåne and Blekinge minus the area in the high risk area within these counties (Table 2).

[i] The total area of potato in Sweden (224.95 km^2) minus the areas with potato in the high-risk areas (24.48 km^2), medium-risk areas (106.93 km^2), Öland (3.80 km^2) and Gotland (6.50 km^2) (Swedish Board of Agriculture 2022).

Table 2. Area cultivated with potato in the high-risk area.

Regions[a]	Land area (km^2)	Total area cultivated with potato (km^2)[b]	Coastline (km) [c]	High-risk area (km^2)	Area cultivated with potato in the high-risk area (km^2) [d]
Laholm	882	6.5	11	55	0.41
Halmstad	1014	3.5	32	160	0.55
Falkenberg	1108	3.5	28	140	0.44
Varberg	869	0.3	37	185	0.06
Kungsbacka	606	0.05	34	170	0.01
Göteborg	448	0.05	34	170	0.02
Torsås	468	0.3	16	80	0.05
Kalmar	956	6.5	52	260	1.77
Mönsterås	599	0.05	30	150	0.01
Oskarshamn	1046	0	50	250	0.00
Västervik	1873	0.05	51	255	0.01
Skåne	10963	111.4	342	1710	17.38
Blekinge	2931	16.0	138	690	3.76
Total	*23763*	*158.5*	*855*	*4275*	*24.48*

[a] The names refer to Swedish counties and municipalities, not cities.

[b] Data from the Swedish Board of Agriculture (2022).

[c] The coastline distance measured in a relatively straight line.

[d] Calculated as the proportion high-risk area of the total land area multiplied with the area of potato.

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