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Systems Approaches for Managing the Risk Associated with the Domestic Movement of Fresh Cherry, *Prunus* spp., Produced in Areas of New York State Quarantined for European Cherry Fruit Fly, *Rhagoletis cerasi* (L.)

Risk Mitigation Document

Final Version

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1. Introduction

1.1. Background and Objective

The objective of this report is to provide a general explanation for a quarantine systems approach for mitigating the risk of establishment of European cherry fruit fly (ECFF), *Rhagoletis cerasi* (L.), in new at-risk (endangered) areas via movement of cherry fruit (*Prunus avium* L., sweet cherry, and *P. cerasus* L., tart cherry) from domestic quarantines in New York State. ECFF was first detected in New York in 2017 (Barringer, 2018). The systems approaches would allow for limited distribution of fresh cherry fruit from the quarantine area to non-cherry producing areas as identified by the Agency. The first systems approach options were evaluated and used before the 2019 season (PPQ, 2018c). Captures of adult ECFF in traps have approximately doubled from 2018 to 2019 (PPQ and NYSDAM, 2019). Therefore, a critical difference in the situation now is that ECFF populations have effectively naturalized in New York State and begun dispersing inland, away from the border with Canada. This report describes an updated systems approach, accounting for the current situation, and the inclusion of some better or newer information on control tactics and on ECFF ecology.

1.2. Fruit fly risks

Fruit flies of the family Tephritidae are important pests of fruits and vegetables worldwide and their presence in areas where the pest is not established represents a significant threat to commercial agriculture and trade (e.g., Norrbom, 2004). Fruit flies represent a particular risk because they lay eggs inside the fruit, allowing immature fruit flies to perhaps develop undetected, at least during the early stages of an invasion. Larval feeding in fruit makes them unmarketable, and in the particular case of ECFF, unusable even for processing (Barringer, 2018; Stamenkovic et al., 2012). The species can harm from 10 to 100 percent of cherry trees in orchards, causing unacceptable losses in many cases (Stamenkovic et al., 2012).

The following are known host plants of ECFF (PPQ, 2018a; Daniel and Grunder, 2012; Liquido et al., 2017):

- Sweet cherry (*Prunus avium* L.)
- Sour cherry (*P. cerasus* L.)
- Mahaleb cherry (*P. mahaleb* L.)
- Black cherry (*P. serotina* Ehrhart)
- Holly barberry (*Berberis aquifolium* Pursh)
- *B. heteropoda* (Schrenk ex Fisch. & C. A. Mey)
- Common barberry (*B. vulgaris* L.)
- Common dogwood (*Cornus sanguinea* L.)
- Alpine honeysuckle (*Lonicera alpigena* L.)
- Tatarian honeysuckle (*L. tatarica* L.)
- Dwarf honeysuckle (*L. xylosteum* L.)
- Common snowberry (*Symphoricarpos albus* (L.) S. F. Blake)
- Coralberry (*S. orbiculatus* Moench)

All of these species may occur in the wild.

Where the risk of fruit fly introduction and spread exists, local, regional and national governments utilize a number of methods to reduce the risk associated with host movement, ranging from outright prohibition of the commodity from potentially infested areas, to approval based on quarantine treatments designed to eliminate the risk. Single quarantine treatments have been shown to be effective for this purpose but can damage the commodity and/or result in reduced shelf life for some commodities. In the last two decades, regulatory officials have embraced the use of "systems approaches" as an alternative means to allow movement of commodities in lieu of using a single or combination treatment (Dominiak and Ekman, 2013; IPPC, 2017, 2018). These methods effectively mitigate the risk posed by fruit flies to acceptable levels where quarantine treatments may not exist, may cause unacceptable damage, or are not practical.

1.3. Need for a systems approach

The quarantine area in New York State is nearly 2,000 square miles (PPQ, 2019a), and encompasses all commercial cherry production areas in the Niagara region of the state (Fig. 1). Under the quarantine none of that fruit is eligible for fresh market sale outside the regulated area, but may be eligible to move for processing, provided the required safeguarding measures for transportation, usage, and remediation of waste are followed (PPQ, 2019c). Methyl bromide fumigation is a possible phytosanitary treatment for Tephritidae larvae, but that option seems to be unavailable in these areas in NY. Therefore, other options are needed to provide some relief for growers within the quarantine area. The proposed systems approach options are intended to achieve this while adequately addressing the fruit fly risk.

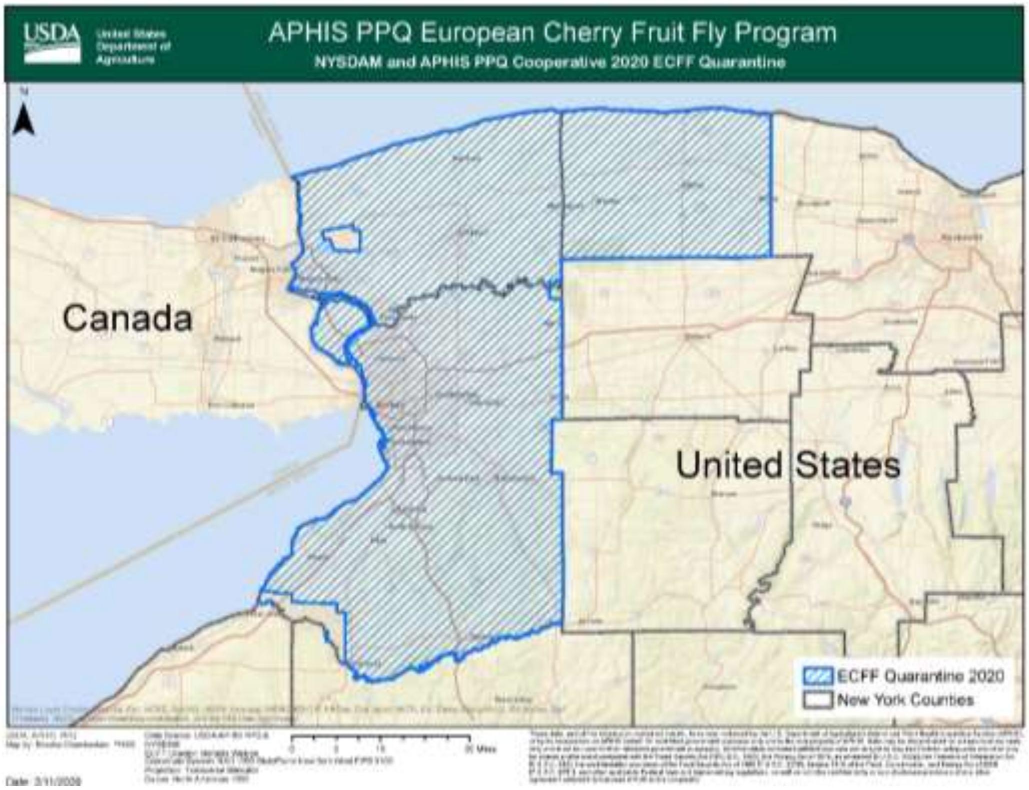

Figure 1. Quarantine map for European cherry fruit fly in New York for 2020.

2. Selection of the Systems Approach Measures and Activities

In this section we present evidence concerning the general usefulness of the selected measures, and specifically for the ECFF systems approach in New York State. The systems approach options evaluated used the following three independent measures or components:

- **Confirmation of Area of Low Pest Prevalence**, as determined by regulatory trapping.
  Following the confirmation of a detected specimen as ECFF, regulatory trapping is implemented throughout the quarantine zone where trap densities are increased in a 100-50-25-20-10 array moving from the core square mile area surrounded by four, concentric, buffer square miles, respectively. Generally, a density of at least 5 traps per mi^2 is maintained throughout the regulated area. Specific trapping is also required in the orchards: at least 1 trap in every orchard and 2 traps for every 5 acres in general. See USDA ECFF New Pest Response Guidelines 2017-01 (PPQ, 2018b).
- **Certified spraying of insecticides**, to kill flies.
  The fruit fly quarantine area covering a 4.5 mile radius around all positive fruit fly sites will be treated with a specified chemical that is yet to be determined. The previous systems approach required the use of GF-120 (Spinosad), a bait spray, but we do not have direct evidence that it is efficacious against ECFF. Some tests of GF-120 have shown promise against related species (e.g., *R. indifferens* Curran [Western cherry fruit fly], in Yee, 2008), but others have not (PPQ, personal communication). Therefore, we took the approach here of modeling insecticide spray efficacy as a generic effect (see below) to determine a minimal efficacy level that provides sufficient risk mitigation; the program managers will specify which chemical(s) meets that threshold (see Appendix I).
- **Limiting distribution of fruit to areas with no commercial cherry production**, to stop infested fruit from getting to endangered areas, as defined by the Agency (i.e., cherry-producing states or regions).

Float test. An additional activity considered below is a “float” test based on sampling fruit, crushing them, and mixing with a sugar solution to reveal the presence of larvae (e.g., Yee, 2014). This is technically not a mitigation measure, but a confirmative sampling test that could usefully help confirm zero/low pest prevalence in some low trap density areas.

2.1. Independent measures

2.1.1. Areas of low pest prevalence

PPQ and the New York State Department of Agriculture and Markets have implemented delimitation and regulatory trapping since 2017. In 2019 over 11,500 traps were placed and monitored in the field, producing over 80,000 collections during the season (PPQ and NYSDAM, 2019; Fig. 2).

The trap being used is a yellow panel trap (“protein-baited yellow sticky card with a lure of ammonium acetate in a polycon dispenser”; PPQ, 2018b). Unfortunately, this trap is not very effective. Based on reports from various researchers (e.g., Lux et al., 2016), we estimated trap attractiveness to be 0.27, which represents very low attractiveness (PPQ, 2020).

Despite having naturalized in some parts of New York State—principally the western boundary of Niagara County (PERAL, 2019)—ECFF has not spread throughout the entire quarantine area (Fig. 1). Its distribution remains patchy, and it may move only about 13 km annually on average (PERAL, 2019). This means some proportion of the production sites in the quarantine area are likely still relatively distant from resident populations. Consequently, we made a technical distinction between higher and lower risk production areas, based on proximity to verified ECFF captures (see below). For the production sites in proximity to ECFF captures, higher trap densities, in combination with zero captures (or one, at most), are used to confirm that population densities remain at levels susceptible to the measures used in the systems approaches. Anecdotal information suggests most captures have come on/near alternate hosts (e.g., honeysuckle) rather than on cherry trees (PPQ, personal communication).

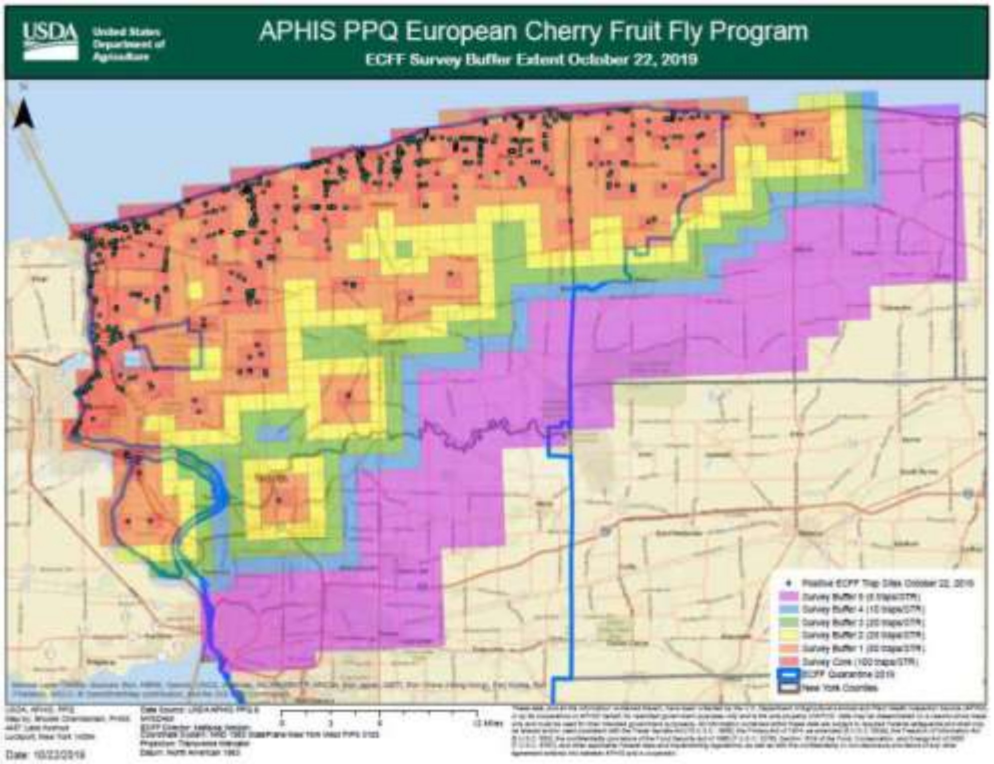

Figure 2. Recent map of the European cherry fruit fly regulated area in New York showing the regulated areas, trapping areas and densities, and positive trap sites.

2.1.2. Certified sprays

Chemical treatments in the production area will be effective as an independent measure if applied preemptively under regulatory supervision (i.e., certification).

Normally we would have a well-defined distribution for insecticide spray efficacy for the given chemical(s), based upon empirical evidence. However, at present we have no agreed-upon chemical, and no empirical data, and are therefore modeling a generic efficacy rate for a required chemical. A number of chemicals are commonly used in New York state for the control of cherry fruit fly (*R. cingulata*), spotted wing drosophila (*Drosophila suzukii*), and other pests (e.g., Agnello et al., 2019; Demchak et al., 2012), and some may prove effective for ECFF. To be eligible for fresh market sale, fruit needs to have been in a production area using that chemical (or one or more of the certified chemicals if multiple options are available) for the entire period before harvest (see Appendix I for 2020 ECFF Program Approved Pesticides).

2.1.3. Limited shipping distribution

The potential risk of fruit shipments comes from the possibility that some infested fruit is shipped to a non-restricted state, and then that fruit is redirected and shipped to a cherry-producing state.

Accordingly, APHIS has stipulated that quarantined New York cherries—even those harvested under the systems approach—should not be moved to the following places (PPQ, 2019b): California; Michigan; Oregon; Washington; and the New York counties of Chautauqua, Columbia, Schuyler, Ulster and Wayne Co. Shipped fruit will have these restrictions marked upon them.

An assessment of the effectiveness of this mitigation was conducted for Mexican Hass avocados (Firco and Podleckis, 2002). Early on, 0.12 and 0.36 percent of the containers shipped to the allowed states were detected in other states, after intentional or inadvertent movement. Later, under more stringent requirements, only about 0.005 percent of containers were detected in other U.S. states.

Reshipment of cherries under a limited permit in boxes or other marked/stamped containers is unlikely to move to prohibited states for the following reasons:

- New York cherries typically are marketed locally or regionally (NYSDAM, personal communication)
- Total production of cherries in New York is relatively small (NASS, 2017)
- Distribution is illegal and subject to fine
- California maintains inspection stations for commercial vehicles transporting agricultural commodities
- Local or regional cherry production in the at-risk areas means very low (or negligible) consumer demand for out-of-market cherries

Therefore, while it is possible that some New York cherries will be moved to the restricted areas, the amount moved is likely to be extremely small.

2.2. Additional activities

We have also considered the use of a ‘float test’ (see Appendix II). This is an examination in which a specified amount of crushed fruit in a placed in a liquid, allowing eggs and larvae to float to the surface and be more easily observed, if present. The lack of such reproductive material in the sample represents a negative result, and is evidence that the sample was not infested. The confidence in the result depends on upon the sample size and the estimated infestation rate. Float tests are commonly required by some entities to allow fruit movement (e.g., Standardization Committee, 2017). Strictly speaking, a float test is not an independent measure, since it does not have a general impact on the fly population. But in this situation, it could help verify that a cryptic population of ECFF is unlikely to be present in the production area, despite the regulatory trapping density being less than that required for the higher risk areas above.

2.3. Summary

Under the proposed systems approach for higher risk areas, fresh cherries (sweet or tart) could move from any orchards within the quarantine area, including the core square mile, if a minimum trapping density was implemented, zero flies (or at most one fly) were captured in the orchard or immediate vicinity, certified spray treatments were carried out for a specified period prior to harvest, and the fruit was shipped only to approved areas.

In lower risk areas, the minimum trap density could be much lower, but the other measures would still be followed, and a float test would be required every week of harvest to guard against the possibility of a cryptic ECFF population being in the production area.

3. Evaluation of proposed systems approaches

3.1. Quantitative risk modeling evaluation

We used a probabilistic simulation model to evaluate and identify systems approach options that reduced the likelihood of a mating pair of ECFF occurring at an endangered area to an acceptable level (PPQ, 2020). The model estimates various state variables and parameters. Chronologically, it estimates the total number of adults in the quarantine fruit area on day one, the total number of mated females, the number of mated females surviving insecticide spray(s) and natural mortality (separately, and in that order) by week, the total number of days of oviposition over all weeks, the total number of eggs laid, the total number of viable larvae from hatched eggs, the likelihood of infested fruit being misdirected to a commercial cherry producing area (endangered area), and the total number of larvae from those fruit that survive to adulthood. The model result (output) of interest was the likelihood of getting one or more mating pairs of ECFF from misdirected infested fruit. That probability was then used to estimate the number of years to the first occurrence of a mating pair at an endangered area.

3.2. Scenarios considered

A critical difference in the situation now versus 2017-2018 is that ECFF populations are no longer adventive; they have effectively naturalized in New York State and begun dispersing inland, away from the border with Canada (PPQ and NYSDAM, 2019). This makes it more difficult to confirm the area of low pest prevalence measure. Therefore, we evaluated the effectiveness of the systems approach across different trap densities. At greater trap densities, with zero ECFF captures (or one, at most), we can be more certain that the population is smaller. Thus, the estimated fly population sizes are greatest at 5 traps per mi^2, and least at 100 traps per mi^2. As previously stated, our modeling objective was to determine the required spray efficacy to achieve a desired level of risk mitigation at each particular trap density.

Detections of ECFF in traps in New York State in 2019 were widespread but still somewhat patchy (PPQ and NYSDAM, 2019). Thus, the first distinction we needed to make was between production areas in proximity to ECFF captures, and those still some distance from captures.

3.2.1. Higher risk production areas

The highest risk production areas are those with nearby ECFF captures, and our quantitative analysis focused first on those areas. Analyses have indicated that the mean annual natural dispersal distance for ECFF is about 8 miles (13 km) (PERAL, 2019). Adding 25 percent of that distance as a buffer, we defined the highest risk areas to be those within 10 miles of a capture. We presume that zero captures, or one capture at most, have occurred within the production area itself.

We modeled scenarios for all trap densities in use, with the exception of 20 traps per mi^2, because that value has no easily mapped square. Thus, we created population size estimates for the densities of 5,[1] 10 (9), 25, 50 (49), and 100 traps per mi^2 (PPQ, 2020). The probabilities of detecting populations were estimated with a trapping network model (Manoukis et al., 2014). Greater trap densities gave smaller predicted estimates for initial population sizes, while lower trap densities result in larger population sizes. For example, the mean number of adult flies in an area associated with a density of 5 traps per mi^2 was almost 3,000, compared to a mean of only 205 for a trap density of 100 per mi^2 (Fig. 3).

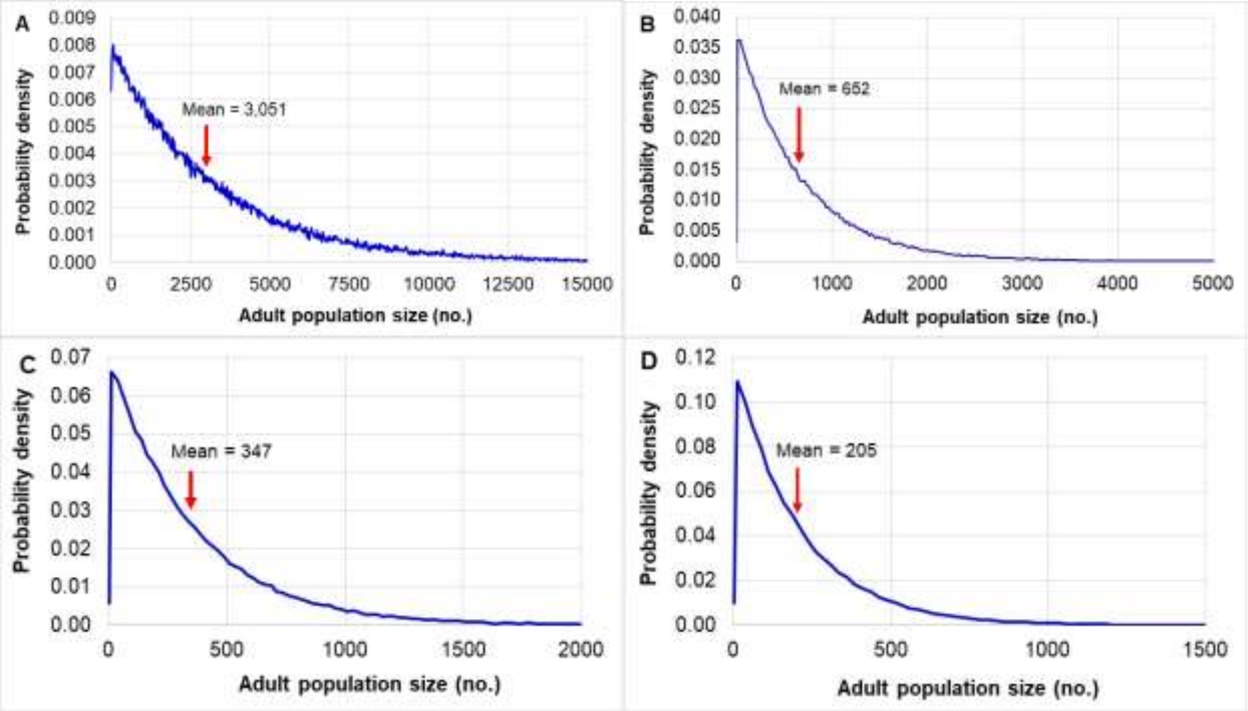

Figure 3. Probabilities for the number of adult European cherry fruit flies in the field when the trap density is (A) 5 traps per mi^2, (B) 25 traps per mi^2, (C) 49 traps per mi^2, and (D) 100 traps per mi^2. Red arrows indicate means.

3.2.2. Lower risk production areas

From above, lower risk areas are those that are 10 more miles away from the nearest ECFF capture. These regulated production areas are still subject to trapping at least at the 5 traps per mi^2 density (with zero detections, obviously) (PPQ and NYSDAM, 2019), and may therefore still

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[1] Mapped exactly as 5 traps per mi^2 rather than approximated as 4 traps per mi^2.

be very low pest prevalence. In those cases, we think the trap density restriction might be waived, provided that all other systems approach measures are followed, and a separate pre-harvest (and weekly) confirmatory test is added. One such test of apparent interest is a "float" test (e.g., Yee, 2014) which looks for the presence of larvae in crushed fruit samples. An inspection based on a float test (or other valid method) would alleviate remaining uncertainties about the possible presence of a cryptic population of ECFF that had not been detected, because of a low density of poor traps.

Because some of these areas legitimately have no or very low populations of ECFF, so we also specified a special, smaller population size estimate for this scenario. This was based on the required in-grove trap density in New York, which is 2 traps per acre, or the equivalent of 256 traps per mi^2. Otherwise, the population size was modeled exactly as described above (§2.1.1).

In addition, we specified that this scenario would use a program-defined version of the float test described above (§2.2). Because this is not a measure taken against ECFF, however, it requires no model specification.

Therefore, the two modeling objectives for the lower risk areas were as follows:

1) Determine the risk associated with using the minimum required spray efficacy from above
2) For the lower population size estimate used for these areas (see below), determine the minimum required spray efficacy.

The first objective tests the impact of using the same certified spray program in these areas that was specified for higher risk areas. The expectation is that safeguarding would improve, since the population sizes are smaller. The second objective is aimed at determining how much the required spray efficacy could decrease, again because of smaller ECFF population sizes.

3.3. Defining a risk threshold for evaluation

Normally we would have a well-defined distribution for insecticide spray efficacy for the given chemical(s), based upon empirical evidence. Using that distribution, model outcomes would indicate whether or not the risk was effectively mitigated, based on the annual probability of a mating pair in an endangered area, and the associated estimate of the number of years to that occurring.

However, at present we have no agreed-upon chemical, and no empirical data, and are therefore modeling a generic efficacy rate for a required chemical. Accordingly, we need to define a standard for acceptable risk mitigation, but no exact or agreed-upon standard exists for determining such a threshold.

Our idea was to set a standard based on ensuring that movement of quarantined fruit in the ECFF systems approach was much less likely to cause establishment in an endangered area than natural spread of ECFF. Thus, we examined the record of spread of ECFF from Canada to New York, and consulted an analysis of potential natural spread to a key endangered area, Michigan. ECFF was first detected in Ontario in 2015, and then in New York State on the border in 2017 (PERAL, 2019). That distance (by land around Lake Ontario) is approximately 200 km, which means ECFF dispersed an average of about 100 km annually (or 8 km monthly) to reach New York. Based on all available information for ECFF, scientists estimated its mean annual spread distance to be 13 km, which implies it could reach Michigan naturally by 2036 (PERAL, 2019). However, if it moved faster—at a maximum possible rate of 40 km annually—it could reach Michigan by 2025.

For the choice of a threshold time period, then, we used ten years, or the approximate average of the two estimated establishment dates. Consequently, our standard was as follows:

- The systems approach should give no more than a five percent chance of a mating pair occurring at an endangered area within ten years

In other words, an approach that gave a five percent chance in nine years would not be acceptable, and neither would a system that gave a six percent chance within ten years. In this range, a viable systems approach should give a value of approximately 200 years as the mean time to a mating pair in a misdirected fruit. This corresponds to an annual probability of about 0.0050. Overall, then, while ECFF may reach Michigan via natural spread within about 16 years on average, the systems approaches we have specified should ensure that establishment via this pathway to *any endangered area in the United States* would take at least 200 years on average (PERAL, 2019).

In all the simulated scenarios below, we increased values of spray efficacy—represented in the model as the likelihood of surviving the spray—incrementally (to the nearest one percent) until the 5th percentile for years to the first mating pair at an endangered area reached or exceeded 10 years.

3.4. Proposed Systems Approach Options

3.4.1. Higher risk production areas

Fruit from areas in proximity (within 10 miles) to ECFF trap captures can be marketed as fresh fruit if the following criteria are met:

- Regulatory trapping has been done in the immediate area at a density of at least 100 traps per mi^2 with zero captures or at most one capture of adult ECFF in the production area
- In-orchard trapping is done at a rate of at least 2 traps per 5 acres, with zero captures or at most one capture of adult ECFF
- Certified spraying has been carried out with a program-approved chemical for at least 30 days before harvest, but preferably for 45 days before harvest
- Fresh market fruit are not shipped to restricted areas

The combination of high trap densities and insecticide use that meets the minimum threshold for efficacy give us some confidence that egg-laying in fruit will be negligible.

In some special circumstances, program managers might determine that negative float test results could be used to maintain eligibility. If done, then the float test sampling protocol would likely need to be more robust for egg/larval detection than the protocol used for lower risk areas, and would have to be stringently followed. This should generally only be considered when the test can provide extra assurance that effective population sizes in the production area remain within the bounds we assessed for the option. It should not be done to justify movement of fruit that were exposed to population sizes larger than those we assessed.

3.4.2. Lower risk production areas

Fruit from areas not in proximity (10+ miles away) to ECFF trap captures can be marketed as fresh fruit if the following criteria are met:

- Regulatory trapping has been done in the immediate area at a density of at least 5 traps per mi^2 with zero captures of adult ECFF in the production area
- In-orchard trapping is done at a rate of at least 2 traps per 5 acres, with zero captures or at most one capture of adult ECFF
- Certified spraying has been carried out with a program-approved chemical for at least 30 days before harvest, but preferably for 45 days before harvest
- Beginning at harvest and continuing until the end of harvest, weekly ‘float’ tests will be carried out with negative results for the presence of any larvae in fruit
- Fresh market fruit are not shipped to restricted areas

3.4.3. Other fruit for processing

All other cherry fruit is still eligible to move to processors, provided that the safeguarding measures described in PPQ (2019c) are followed.

4. Summary of risk

4.1. Required spray rates for higher risk areas

Relatively high spray efficacy rates were required for all five different tested trap densities (Table 1). As expected, the required mortality rate was lowest for areas under 100 traps per mi^2, but the result of 0.71 still seems relatively high, and it may be challenging for managers to certify a chemical or combination of chemicals that meet that threshold. At the other end, with either 5 or 10 traps per mi, the required mortality rates are so large—96 or 97 percent—that meeting that threshold seems unlikely.

Table 1. Model results for higher risk cherry production areas in New York State showing the ECFF spray survival rate and associated mortality rate required for each area trap density (no. per mi^2), as well as the likelihood of a misdirected mating pair, and the mean years to the first mating pair with 5th percentile.

Density	Required spray rates		Mating pair	Years to first mating pair in endangered area	
	Survival	Mortality	likelihood	Mean	5th Percentile
5	0.03	0.97	0.00434	230	12
10	0.04	0.96	0.00442	226	12
25	0.13	0.87	0.00567	176	10
50	0.20	0.80	0.00514	195	10
100	0.29	0.71	0.00543	184	10

Examination of model results for impacts of the measures on ECFF indicated that any option in which the mean number of eggs laid increased much above 1,100 would be untenable. Spray efficacy requirements needed to reduce the ECFF population size to an average of 35 to 45 mated females in the production area.

4.2. Evaluations for lower risk areas

Recall that for lower risk areas the trap density can be the minimum of 5 traps per mi^2, except within orchards where it is still 256 traps per mi^2 (2 traps per 5 ac). Also, we simulated these scenarios with a ECFF population size estimate lower than the smallest estimate used above for higher risk areas.

For these areas we made two determinations: 1) the risk associated with the use of a chemical (or chemicals) meeting the efficacy standard from above, and 2) the minimum spray efficacy required for the minimal population size estimate. The latter information might represent a "last resort" systems approach for the lowest risk areas if the spray efficacy level required for higher risk areas cannot be achieved.

4.2.1. Risk with spray efficacy level for higher risk areas

At the density of 100 traps per mi^2, the required spray mortality rate was 0.71 or more [*p*(surviving spray) ≤ 0.29]. Using that value in the model with the lower population estimate from the use of 256 traps per mi^2, the annual probability of a mating pair in an endangered area decreased by 83 percent, to 0.00092 (Table 2). The mean number of years to that occurring was 1,087, with a 5 percent chance of happening within 56 years. As expected, this is significantly safer than for higher risk areas (Table 1).

4.2.2. Risk with spray efficacy minimized for lower risk areas

When we allowed *p*(surviving spray) to go above 0.29, we found that the minimum efficacy rate required for these areas was 0.52 (Table 2). In other words, the required mortality rate for the chemical was only 0.48, which should be easier to meet than the rates needed for higher risk areas.

Table 2. Model results at three selected probabilities of surviving insecticide sprays (see text) for the ECFF systems approach for lower risk production areas, showing the probabilities of a mating pair occurring in an endangered area, and the years (mean and 5th percentile) to the first such pair occurring.

***p*(surviving spray)**	***p*(mating pair)**	**Years to first misdirected mating pair**	
		Mean	**5th percentile**
0.29	0.00092	1,087	56
0.52	0.00557	180	10
0.53	0.00592	169	9

4.3. Selected risk modeling caveats

The simulation model is designed to be realistic and accurate, but we sometimes make assumptions that likely lead to overestimating the risks somewhat. This is done in part to simplify the model, but these specifications also act to minimize the consequences of any unknown errors [e.g., underestimating *p*(surviving spray)], if they arose. For example, assuming that all surviving females will successfully mate is an assumption that will tend to overstate how many eggs are laid, but we feel it is worth making because we expect that proportion to be high anyway (some evidence supports that). For a full explanation see PPQ (2020), but following are selected assumptions and caveats built into this analysis, and their possible impacts on the estimated risks.

- We assume every surviving female is mated, which directly increases the number of eggs laid. The true proportion may be, on average, about 93 percent (Katsoyannos et al., 2000). We do not know how well those conditions would match these.
- Available evidence suggests that ECFF oviposit only one egg per cherry fruit (Fletcher, 1989). Assuming this in the model maximizes the number of infested fruit available to be misdirected.
- When calculating the likelihood of getting a mating pair from infested fruit at the endangered area, we assumed that all larvae are together in time and space. Fruit harvested at one time from an infested grove could reasonably be grouped together, but that is less likely over several weeks of harvesting, as represented in the model, or with multiple varieties which ripen at different times.
- The model results are probabilities of a mating pair occurring at an endangered area, but successful survival and establishment of the population requires additional processes (e.g., escaping into the environment, finding a host, surviving natural mortality). Minimizing the chance of getting a mating pair at the endangered area is more tractable, and leaves those remaining processes as an additional buffer against establishment.

5. Conclusions

Based on the justifications for the independent measures above and the quantitative modeling results the following systems approaches provide acceptable pest risk reductions for ECFF in quarantined cherry fruit from New York state for different situations.

Fruit from higher risk quarantined areas can be shipped fresh from anywhere when the following conditions have been met (*Option 1*):

- At least 30 d of regulatory trapping at a minimum density of 100 traps per mi^2 with zero captures or at most one capture of an adult ECFF in the production area
- At least 28 d of weekly certified sprays before harvest, continuing until the end of harvest, using one or more chemicals as specified by program managers to achieve a mortality rate of at least 0.71
- A shipping restriction for certain specified states and counties

Higher risk quarantined areas are those within 10 miles of a validated capture of an adult ECFF. With regard to validated captures of ECFF in production areas, program personnel will decide based on local circumstances whether or not a capture changes the eligibility status of particular defined sections (e.g., blocks, groves, orchards).

In certain circumstances, PPQ ECFF program management personnel may also decide that fruit which might otherwise not be able to ship fresh, could maintain eligibility if weekly negative float tests are completed. The sampling protocol for such tests would be defined by the program managers.

Fruit from lower risk quarantined areas can be shipped fresh from anywhere when the following conditions have been met (*Option 2*):

- No validated captures of an adult ECFF within 10 miles of the production area
- At least 30 d of regulatory trapping at a minimum density of 5 traps per mi^2 with zero captures of an adult ECFF in the production area
- At least 28 d of weekly certified sprays before harvest, continuing until the end of harvest
- Weekly negative float tests for the presence of any larvae in fruit, beginning with first harvest and continuing until the end of harvesting
- A shipping restriction against certain specified states and counties

For the certified spray, growers should use one or more chemicals as specified by program managers to achieve a mortality rate of at least 0.71, or, if that efficacy level is unattainable, program-approved spray(s) which achieve a mortality rate of at least 0.52. As above, PPQ program management personnel will decide based on local circumstances whether or not a capture changes the eligibility status of particular production areas, and may also require a short delay after any fly capture before continuing harvest, to verify continued low pest prevalence.

All other fruit can be shipped under certification for processing (*Option 3*), following the procedures described in PPQ (2019c).

6. Acknowledgements

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Appendix I
2020 ECFF Program Approved Pesticides for Systems Approach

1A	Sevin 4F	2-3 qt/acre	carbaryl
1A	Sevin 80 Solupak	2.5-3.75 lb/acre	carbaryl
1A	Sevin XLR Plus	2-3 qt/acre	carbaryl
1B	Imidan 70W	2.13 lb/acre, or 0.75 lb/100 gal	phosmet (not on sweet cherry)
3A	Asana XL 0.66EC	4.8-14.5 fl oz/acre, or 2-5.8 fl oz/100 gal	esfenvalerate
3A	Baythroid XL 1EC	2.4-2.8 fl oz/acre	cyfluthrin
3A	Warrior II 2.08CS	1.28-2.56 fl oz/acre	lambda-cyhalothrin
4A	Assail 30SG	5.3-8 oz/acre	acetamiprid
4A	Assail 70WP	2.3-3.4 oz/acre	acetamiprid
5	Delegate 25WG	4.5-7 oz/acre	spinetoram
5	§Entrust 2SC	4-8 fl oz/acre, or 1.3-2.7 fl oz/100 gal	spinosad
5	§Entrust 80WP	1.25-2.5 oz/acre, or 0.42-0.83 oz/100 gal	spinosad
5	GF-120NF	10-20 fl oz/acre	spinosad & bait
28	Exirel	10-17 fl oz/acre	cyantraniliprole

Appendix II
Brown Sugar Float Method

The amount of fruit that would need to be sampled to support certification of the fruit as being un-infested with ECFF larvae is outlined in the report "Brown sugar flotation to detect fruit fly larvae in host fruit" prepared by T. Shelly, PPQ S&T, December 2019. The report is on the FF Sharepoint site at: https://usdagcc.sharepoint.com/sites/aphis-ppq-scitech/cphst/FF/Regulatory%20%20Control/Forms/All%20Documents.aspx?viewid=85e70f34%2Dd4cf%2D4048%2D948a%2D3423b0cddf27&id=%2Fsites%2Faphis%2Dppq%2Dscitech%2Fcphst%2Fff%2FRegulatory%20%20Control%2FECFF%20%2D%20European%20Cherry%20Fruit%20Fly%2F2020%20Reports%20and%20Recommendations

The following is excerpted from the Shelly report:

Description of sampling protocol for cherries to determine the level of fruit fly larval infestation using the brown sugar float method
To meet the requirements for shipping fruit out of quarantine from orchards with positive trap captures the following sampling protocol is recommended for subsequent processing using the BSF method. It follows the requirements for Master Permit QC906 (CDFA 2019) for the shipment of cherry fruit from British Columbia, Canada, to California with concerns for cherry fruit fly.

The recommended sampling procedure includes the following:
(1) To determine the number of cherry fruit to sample, the weight of the fruit should be converted to 20-pound container equivalents.
(2) Shipment Lot Weight – Number of cherries randomly sampled/20-lb container

Lot Size in Pounds
1,000 to 19,999 lbs – 5 cherries/20 lbs
20,000 to 39,999 – 4
40,000 and over – 2

There are approximately 80 cherries per pound, so for 1,000 lbs of fresh tart cherries you would need to randomly sample 250 individual or 3.1 lbs of cherries.

Outline of brown sugar flotation method used by Yee (2012, 2014) to detect *R. indifferens* larvae in cherries
Randomly sampled cherries from packing containers as described above should be processed as follows. This method also conforms to the process approved for shipping cherries from BC, Canada, to California (CDFA 2019):

- Cherries stored at 3-4°C until crushing about 24 hours after collection
- Crush cherries in standard packinghouse cherry crusher (no difference in larval detection was apparent using crusher gap widths of 2mm or 5 mm)

- Make brown sugar solution by adding 3.18 kg of brown sugar to 18.9 L water (= 7 lbs in 5 gal) and stirring thoroughly.
- Add 2 mL of anti-foamer (10% dimethylpolysiloxane; Genesis Agri Products Inc., Yakima, WA) at a rate of 15 mL to 15 L of the brown sugar solution
- Solution should be checked with a refractometer and a Brix reading of > 15^{o} should be obtained to guarantee good larval flotation.
- Place 454 g of cherries in crusher; 2 L of BS solution added to rollers and into tub (blue plastic, 30 by 25 by 14 cm; L:W:H) with smashed cherries (liquid in tub should be approximately 3 cm depth).
- Let tub sit for 5 minutes; cherries will sink, larvae will float and be visible against dark solution
- Check surface for floating maggots for 5 min; stir cherry mush gently to loosen larvae