Hort Innovation

Final Report

Developing a national systems approach to access key Asian markets

Project leader:

Dr Rieks Van Klinken

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Level 7
141 Walker Street
North Sydney NSW 2060

Telephone: (02) 8295 2300

www.horticulture.com.au

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Public summary

Maintaining and growing exports is critical for the horticultural industry and is heavily dependent on providing trading partners with confidence that biosecurity risks are managed effectively. Often this is achieved through the use of a single-point treatment like cold treatment or fumigation. Such phytosanitary measures are not suited to all commodities or markets, or can affect quality, be expensive, or logistically challenging to implement. Phytosanitary systems approaches (PSA), where two or more independent measures are combined to manage risks, offer an alternative. An important advantage of PSAs is that they are compatible with modern production and supply chain practices where systems approaches are commonly already being used for pest management. However, PSAs are underutilized owing in part to difficulty in determining how effective they are in reducing risk, and the perceived cost and complexity of implementation.

This national, collaborative project aimed to support the broader utilization of phytosanitary systems approaches through the development of quantitative risk tools, testing and refining of these tools through commercial application, and by extensive engagement with industry, regulators and the scientific community. The cherry, citrus, berry and apple industries participated in project case studies.

This project has achieved far-reaching benefits for industry. For the first time industry and regulators have a tool kit they can use to quantify biosecurity risks of trade, and to develop, assess, negotiate and cost the best set of phytosanitary measures to manage those risks. Confidence in these approaches was achieved through commercial application, with over 17,000t of cherries produced alone under our trial PSA, with no infested fruit being detected. Case studies led to direct benefits to industry through new or improved trade protocols, including a systems approach protocol for cherries which is now in final stages of endorsement, the simplification of existing protocols for diverse commodities, and data sets to support future market access improvements (apples, citrus, cherries and berries). Development and application of the risk tool kit, together with extensive engagement (9 papers published or in late stages, and over 50 presentations and workshops), has led to a much greater understanding and acceptance of phytosanitary systems approaches. It has also led to the broader application of systems-thinking and risk science generated through this project into the management of trade-related biosecurity risks. As a result of this engagement all domestic and federal regulators are committed to supporting efforts to embed project findings into practice. Having a common approach to how biosecurity risks are managed across levels of Government and between state jurisdictions (harmonization) is critical for industry.

While this project set out to support the development of PSAs, the resulting risk tool kit has far wider applications. By bringing a quantitative approach to risk management it will help further strengthen our national, risk-based biosecurity system, thereby maintaining our competitiveness whilst protecting our industry from biosecurity threats.

Further information on this project, and access to risk tools, can be found online (https://research.csiro.au/psa/).

Keywords

Apples; berries; cherries; citrus; market access; medfly; phytosanitary systems approaches; Rubus, Queensland fruit fly, strawberries.

Introduction

Continued growth of the Australian horticultural industry is dependent on maintaining and extending our export markets. To achieve this, importing countries require assurance that trade-related biosecurity risks are being effectively managed through risk assessment and the setting of entry requirements to manage any unrestricted risk. Internationally agreed principles for setting entry requirements are set out under the WTO-SPS agreement and detailed in International Standards for Phytosanitary Measures (ISPMs) (World Trade Organization 1994). It is important that entry requirements are both effective and least-trade-restrictive. Widely used entry requirements for high-risk quarantine pests (such as fruit flies) are area-freedom, demonstration of non-host status, or the use of an agreed end-point treatment such as extended cold treatment, irradiation or methyl bromide fumigation. Phytosanitary Systems Approaches (PSA) offer an alternative approach, where two or more independent phytosanitary measures are combined to manage risks.

PSA are compatible with how the horticulture industry typically manages biosecurity risks and pest management issues. In fact, they offer enormous potential for industry as many existing commercial production and supply chain practices can be included as entry requirements where they are shown to reduce risk. Additionally, a combination of measures can be considered that are less trade restrictive, costly or detrimental to product quality, than an end point treatment.

PSA were first proposed in the 1980s. Although recognized in many domestic and international trade protocols they are nonetheless generally viewed as being underutilized. An important barrier to use is the difficulty in quantifying the effectiveness of PSA. Aspects of PSA implementation can also be more complex and costly for industry and regulators.

This national project was a collaboration between industry, researchers and regulators to help Australian horticultural enterprises realise market opportunities in Australia and Asia. It aimed to, for the first time, develop a practical, quantitative methodology for evaluating the efficacy of PSA that would be acceptable to regulators. Development of this model, together with active engagement with relevant scientific, industry and regulatory communities, was aimed at improving both the confidence biosecurity regulators have in the efficacy of PSA, and to enhance opportunities for domestic (and ultimately international) adoption. The project also sought to provide industry with the guidance they need to critically assess the potential benefits of PSA for their industry.

Methodology

This was a national collaborative project, led by CSIRO in partnership with the NSW, WA and Victorian governments and industry. Project governance was structured to maximise national engagement and uptake. An advisory committee represented by leaders from DAWE (Department of Agriculture, Water and Environment), PHA (Plant Health Australia) and relevant industry bodies provided strategic guidance. The project was structured into Working Groups with a Project Leadership Team represented by each agency and working group taking responsibility for overall project delivery.

The overarching scientific objective of this project was to develop documented PSA tools that can be adopted by industry, initially for the domestic market through the case studies, but ultimately adapted for the export of a wide range of commodities. The industry goal was to increase export opportunities into Asia, noting that domestic use of the PSA is expected to be a pre-condition for acceptance by international trading partners. As a PSA may be more acceptable to non-Asian markets (and that the Commonwealth negotiation strategy may include easy wins into these markets to build momentum), the project focused on broad international standards and acceptability.

To achieve this the project developed a quantitative approach for assessing risk within a PSA that will be acceptable to regulators and industry, and that will be readily customisable to a wide range of commodities, pests and trading partners. Identifying the approach that will be most acceptable for regulators and industry was critical. This was achieved through extensive, iterative consultation with DAWE, state and territory regulators, industry and the international scientific community to develop an agreed list of specifications that the approach needed to meet, and to test and evaluate the models during development.

CSIRO was responsible for developing the models, undertaking analyses, and for the engagement activities necessary to ensure that the risk tool kit had the best chance of being accepted by regulators and industry. Partnering state departments contributed to the overall project goals, and led case studies to provide real-word testing and feedback needed to refine the modelling approach. Case studies were determined by where participating industries have identified the development of PSA as being important for market access, and where at least one of the participating states had expertise and could lead the work. Resulting state-led case studies included cherries, berries, apples and citrus.

This was a dissemination project with all outputs to be made publicly available, provided there areno trade sensitivities. This was consistent with the goal of developing a tool kit that is internationally accepted, readily available to industry and regulators, and can be further developed and refined by the trade-risk community. As a result, research has or is being made, publicly available through publication. Methodology of each project component is described in general terms below. Details can be obtained from the publications, Hort Innovation or the authors.

Results and discussion

Results and their relevance to the horticultural industry are described against the six primary project deliverables.

Deliverable #1. A peer-reviewed, international review of systems approaches.

PSA used in horticultural trade were reviewed, resulting in the development of an easily implementable risk framework for developing and assessing PSA (van Klinken et al. 2020). A review of 60 publicly available, international and domestic protocols documented 327 measures in use. These measures were classified according to how they reduce risk and where in the production or supply chain the risk was reduced. This is a significant advance on previous attempts at classifying measures that only focused on where measures were applied. A follow-on paper (van Klinken et al. 2021) was written in response to a critique of our first paper (Quinlan et al. 2021) and clarified the respective roles of risk science and protocol implementation.

This risk framework was subsequently extended to be applied to any commodity, and to include measures that captured both commercial activities that reduce risk and may contribute to pest risk assessment, and regulated measures mandated to manage risk (van Klinken et al. subm.). The result was a "menu" of 39 measures generated from over 1,800 measures identified in the literature, classified within a risk framework (Figure 1). The risk framework identified four risk reduction objectives (minimizing exposure to pest, minimizing vulnerability of the commodity to the pest, reducing infestation rate and reducing establishment risk) that could be applied against one or more consignment stages (production, post-production and post-border).

Impacts. This risk framework and menu of measures provides a versatile basis for developing and assessing new and more innovative protocols that are both effective and least-trade-restrictive, thereby helping to facilitate safer and more open trade of fresh produce. It also serves an important role in communicating how measures reduce risk and underpins the development of our quantitative risk tools. Some of the identified measures were rarely reported, suggesting that they are underutilized.

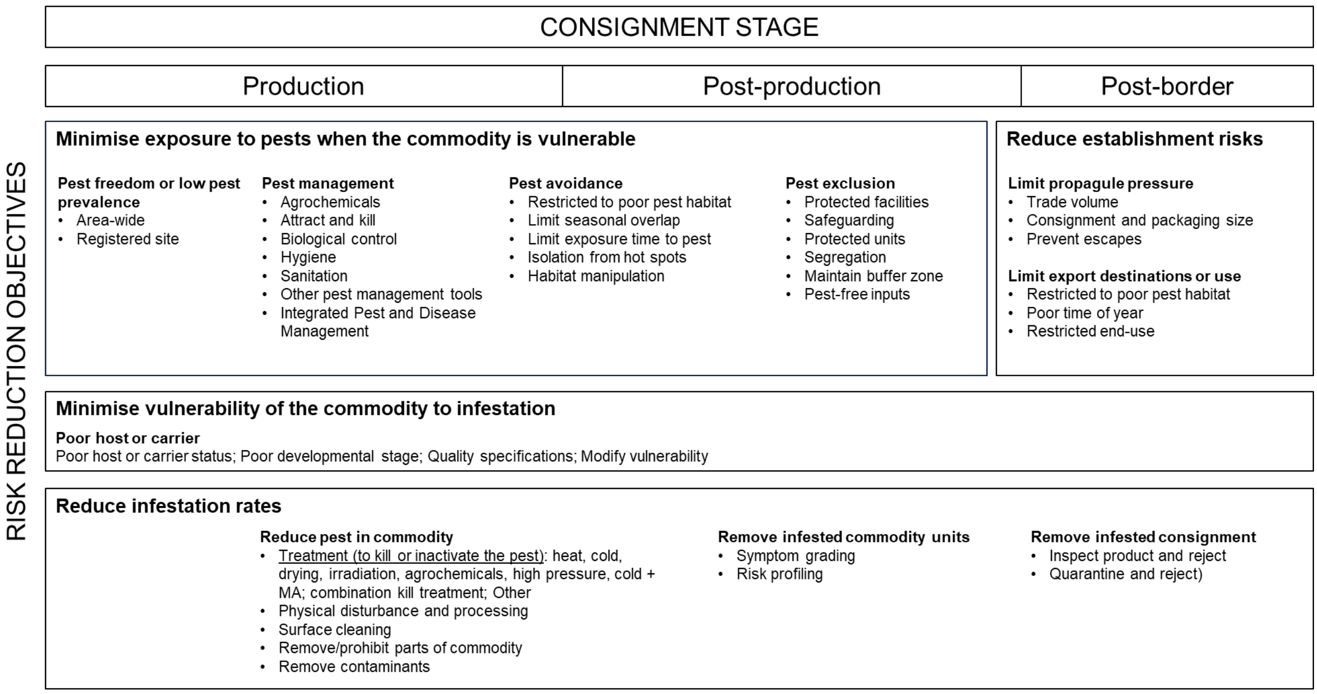

Figure 1. Menu of measures, which groups measures into measure categories under each risk reduction objective, and identifies the consignment stages against which each risk reduction objective mostly applies.

Deliverable #2. A quantitative systems approach methodology that is acceptable to regulators and industry.

The primary scientific goal of this project was to develop a quantitative methodology for assessing the efficacy of measures, individually and in combination, to reduce risk. This was achieved through the development of PRReSTo, a Pest Risk Reduction Scenario Tool. However, a range of complementary tools were developed to further support phytosanitary systems approaches (Figure 2). Generality of application was sought at every opportunity. As a result, this tool kit is broadly applicable to managing trade-related biosecurity risks. An overview of the main tools is provided below, except for The Risk Reduction Framework which was described under Deliverable #1 and the comparative cost calculator which is described under Deliverable #4.

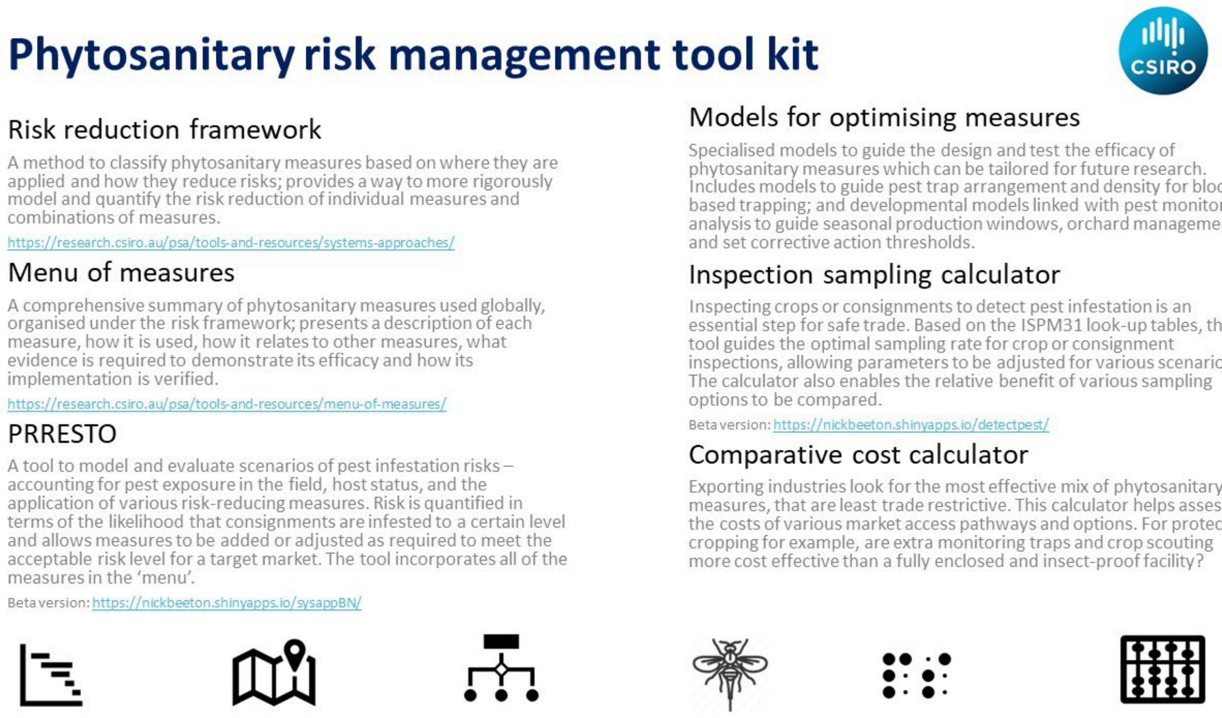

Figure 2. Overview of the Phytosanitary risk reduction tool kit developed through this project. This tool kit provides a set of quantitative methodologies and models to support the design of phytosanitary measures and to assess the efficacy of measures, individually and in combination, for reducing biosecurity risks

<u>Menu of measures</u>

A "menu of measures" was developed that groups measures identified through international literature review against the risk framework – that is, according to how they reduce risk and where in the supply chain they may be applied to reduce risk (Figure 1). A "Menu of Measures Resource" was written which provides a detailed description of each measure, how it is used, how it relates to other measures, what evidence is required to demonstrate its efficacy, and how its implementation is verified (van Klinken et al. in prep). This resource has been reviewed by DAWE and will be made publicly available once the supporting paper (van Klinken et al. subm.) has been peer-reviewed at an international journal.

Impact. This menu of measures allows for the first time industry and regulators to consider the full breadth of potential options for managing trade risks, and what would be required to have them recognized. It is a useful tool for designing, evaluating and improving entry requirements. It also identifies where more research is needed to support the wide use of measures that could be effective but are not widely adopted.

PRReSTo: Pest Risk Reduction Scenario Tool

A wide range of measures can be used to reduce risk (Figure 1) but prior to this project there was no way to quantify biosecurity risk of horticultural trade and evaluate the individual and combined effects of risk-reducing measures in a common framework. In this project we developed PRReSTo (Pest Risk Reduction Scenario Tool) to address this gap. Infestation rate within a consignment is estimated by taking into account exposure to the pest and host vulnerability. The effect of applying different measures on fruit infestation rate can then be quantitively compared. The model has been validated and applied to show that requirements for managing risks can be greatly reduced if confidence can be given that the risk of pest exposure is low (Froese et al. in preparation). The original model was built in Netica, which is a Bayesian Network software that allows users to run scenarios. An independent Bayesian network model was then built using R, with a web-interface front end, allowing for ease of deployment and wider use. The current model was designed and tested for fruit flies, but was developed such that it could be readily adjusted to apply to diverse pests and commodities.

Impact. Assessing and comparing how multiple measures, individually and in combination, contribute to reducing risk has been a major challenge for regulators, and an impediment to the widespread use of systems approaches. We first applied PRReSTo to support the phytosanitary systems approach for cherries. This helped regulators to understand, accept and value the approach. I At the request of regulators it has since been applied to a wide range of risk assessments and protocol evaluations.

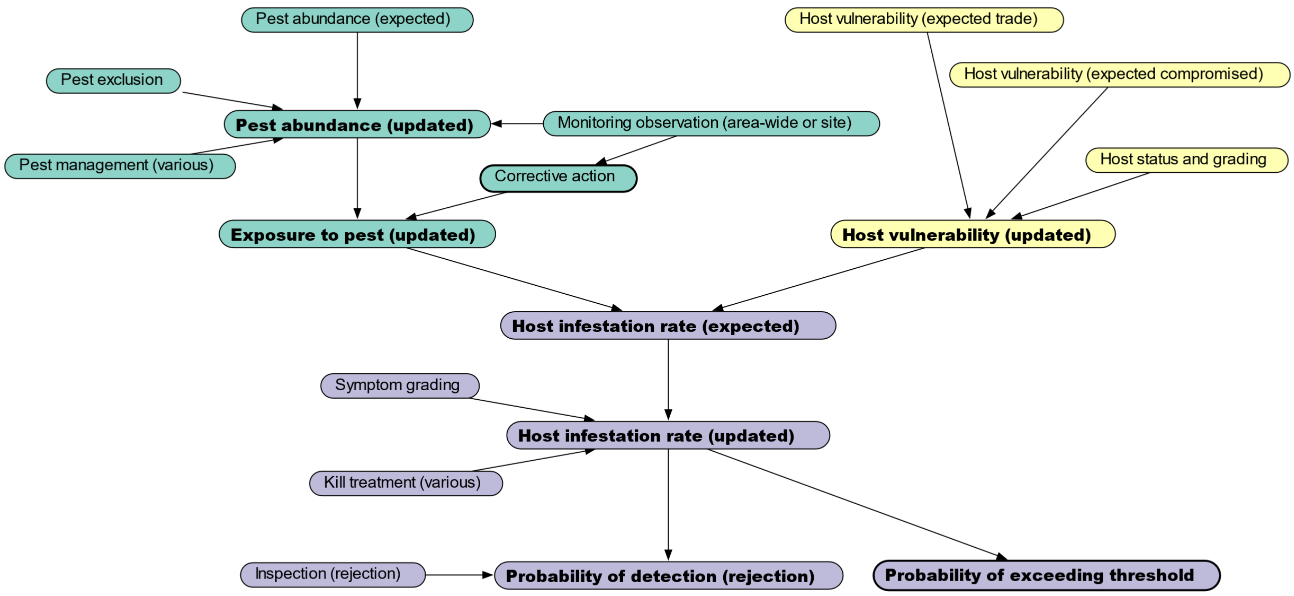

Figure 3. A simplified representation of the PRReSTo model structure. The model has three (colour-coded) parts consistent with the risk reduction objectives identified in van Klinken et al. (2020): exposure to pest (green), host vulnerability (yellow) and host infestation rate (purple). Response variables, each of which is connected to multiple influencing variables, are highlighted in bold.

Surveillance design model

Pest surveillance, coupled with a corrective action if a detection threshold is exceeded, is an important measure in many phytosanitary systems approach protocols. Surveillance can be either conducted “area wide” or be restricted to the registered block. Limiting surveillance to the registered block has the advantage of allowing producers to be responsible for managing their own risks (i.e. they will not be suspended from trade if pests are found in other orchards within the area) and is more readily overseen by regulators. However, for mobile pests such as fruit flies, block-based surveillance needs to be effective at detecting pests already in the block as well as pests that might enter the block from nearby, including undocumented pest aggregations, or ‘hot spots’. A model was developed to evaluate detection probabilities of different trap arrangements, and hence guide the optimal placement of traps for block-based surveillance (Hill *et al*. in preparation). The model considers trap attractiveness, trap density and trap layout on the likelihood of pests at varying densities (including very low) being detected within a block. Additionally, the rate at which the flies move within the orchard and whether the flies originate from within or outside the orchard can be investigated. This work is a collaboration with USDA colleagues who proposed the initial model (Manoukis et al. 2014), although extends on it in important ways to make it applicable to block-based surveillance. A series of analyses using this model supports that for block-based detection a regularly spaced trap array is best. In practice this can be most easily applied using a “maximum distance from trap to tree” rule. Moderate trapping density (5 traps per 10 ha in our scenario) was sufficient for detecting very low pest numbers. Our model was written such that it can be readily extended to other pests, commodities and environments.

Impacts. This modelling has helped inform the trapping regime being used in the PSA cherry and citrus protocols. The model is applicable to a wide range of pests and trapping scenarios. Wider application of this methodology is expected to lead to greater acceptance of block-based trapping. It will also help calibrate block-based trapping to the level of risk that is being addressed.

<u>Phenology modelling and trap data</u>

To support the cherry data package, we developed a suite of functions in R that couple observations (trapping data) with pest phenology (using development models) to return concise and informative overviews of regional- and orchard-level pest pressure data. While developed for fruit flies and the cherries case study, these tools are general enough that they can be readily adapted to other pests and case studies to demonstrate measures such as limited phenological overlap, and historical pest pressure across multiple seasons. Specifically, we developed functions to turn raw trap data into standardized units for a given property or region (e.g. flies per trap per day, FTD). We also developed functions that could extract and summarize weather data for given locations, and then allows us to determine key dates for management (e.g. first day after winter when the temperature threshold is met for mating). Further, we used development models for species such as fruit flies from the literature so that phenological development could be incorporated into visualizations and analyses to communicate risk posed by timing of pest generations for a given location.

Impacts. A vast amount of trapping data is obtained by industry and government for a range of purposes, including as a market access requirement. The suite of functions developed here makes it much simpler to generate additional value from such data in a standardized way, as demonstrated through their use in generating the cherry data package. The functions are written such that they can be readily applied to other pests and applications. Future applications include combining data with additional pest phenology models to better understand pest development based on location and seasonality.

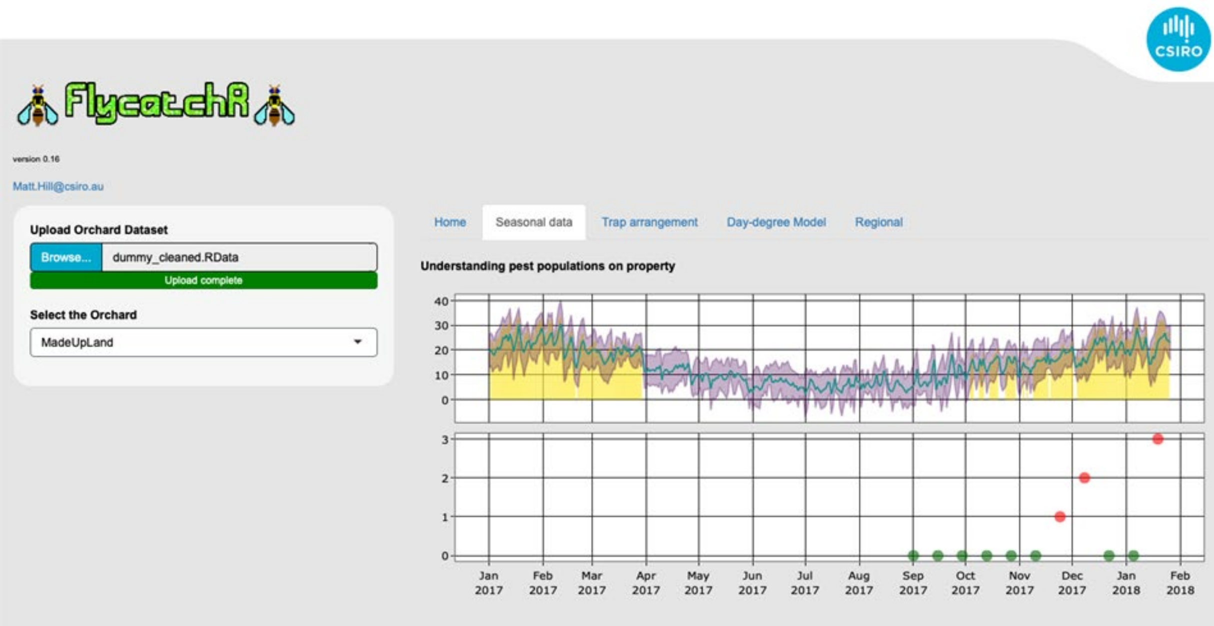

Figure 4. Prototype FlycatchR output to visualise trapping data alongside weather data and phenological models. This app allows for the trapping data for an orchard to be displayed alongside key weather information. The ‘seasonal data’ panel of the app shows the daily temperature range (purple band) with the temperature average (blue line) and yellow bars for the days where the temperature was above 16°C at dusk – a threshold for mating. Trap clearance dates are shown in green and red, with red indicating positive trap clearances. Other features of the app include being able to run phenological models in reverse to identify critical periods for fruit fly development and spatially visualise trap catches across a season.

Inspection sampling tool

Inspection of fruit is a standard entry requirement. Most commonly this involves an inspection of 600 pieces of post-graded fruit. ISPM31 (IPPC Secretariat, 2016) outlines the statistical methodology for calculating the likelihood of detecting infested fruit at different sampling rates and detection likelihoods, and provides look-up tables for common scenarios. For example, inspecting 600 fruit results in a 95% chance of detecting infested fruit if the fruit infestation rates is 0.5% (1 in 200 fruit) and an infested fruit is always correctly classified as such if inspected. We develop a web-based sampling tool application that allows users to explore their own scenarios. Furthermore, we extended the statistics to allow: i) inspection of high-risk fruit (such as from the reject bin) to be assessed; and ii) crop inspection to be quantitatively evaluated for the first time. Inspection of high-risk fruit is much more sensitive than inspected packed fruit. Multiple crop inspections also increase the likelihood of detecting infested fruit, especially if they are targeted at high risk (e.g. damaged or early-maturing) fruit, although further work is needed to refine the statistics supporting crop inspection. The statistical model underlying the sampling tool was also used to parameterize and help validate PRReSTo.

Impacts: This sampling tool was used to support the addition and design of a crop inspection measure to the cherry and citrus PSA's, where crop inspection was already widely utilized by producers. The tool has also been used by regulators to test whether existing protocols could be strengthened through additional inspection. For that application it demonstrated that increasing sampling effort had a limited effect, and therefore the inclusion of other measures should be considered. Further refinement of this tool will allow the risk-reducing benefits of such practices to be better acknowledged when assessing phytosanitary risks and setting entry requirements.

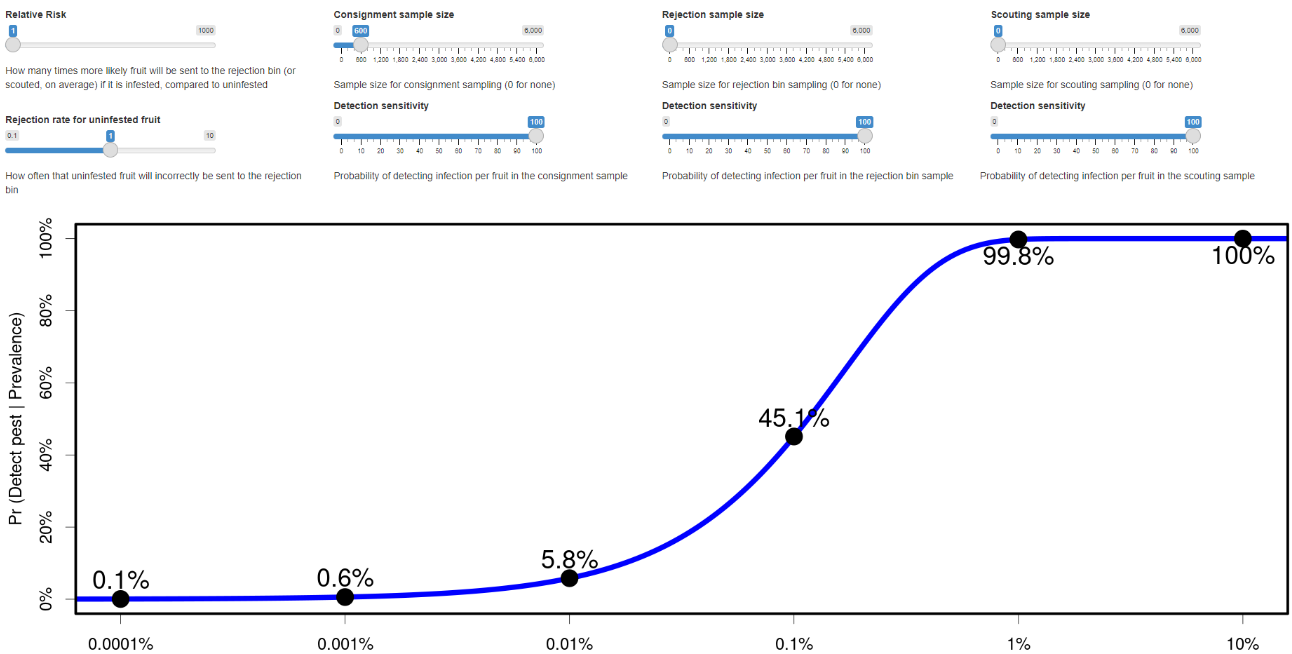

Figure 5. A screen shot from the on-line sampling calculator. Sliders allow users to examine the effect of sample size, detection sensitivity and sampling method (packed-fruit, sampling of rejected fruit and crop scouting) on the likelihood of detecting infested fruit at different fruit infestation rates (X Axis). In this example, a 600 piece fruit sample of packed fruit only detect an infested fruit 5.8% of the time if the actual fruit infestation rate is 0.01% (1 in 10,000 fruit), assuming a 100% detection sensitivity.

Method for evaluating protocol efficacy from compliance data

Considerable compliance data is collected to meet the entry requirements of trading partners. This often includes in-field surveillance data and post-harvest fruit inspection data (typically 600-piece fruit inspections). We developed an analytical approach that utilizes this combined data to quantitatively estimate confidence in the overall trade protocol (Caley et al. in preparation). This analytic demonstrates that it is possible to gain high confidence that production systems have negligible risk, based on repeated observations of no, or very low, pest prevalence within inspected produce. It also shows how key data gaps for quantitative models (e.g. the probability of infestation at harvest) may be estimated.

Impacts: This methodology was applied to surveillance and fruit inspection data generated during the cherry systems approach case study to give additional assurance regarding the high efficacy of the proposed protocol. If linked to live data streams, such as through AusPestCheck, this methodology could be applied to identify where trade-risks are emerging so that they can be addressed before becoming an issue with trading partners. When combined with historic trade data this methodology also has the potential to support the negotiation of market improvements or new markets based on past performance.

Deliverable #3. Testing, refinement and acceptance of methodologies by regulators through case studies

Development of the risk tools was guided by case studies and other interactions with industry and regulators, and the refinement and acceptance of these tools was achieved through their application in active trade issues and negotiations. At conception this was to be achieved through the development of three, new, systems approach ICAs (Interstate Certification Assurance) for interstate trade. As work and consultation progressed our efforts focused on applying the science to a broader range of priority, trade-related biosecurity issues that individual states and the Subcommittee for Domestic Quarantine and Market Access (SDQMA) were confronting. The later approach proved to be a particularly effective way to test, refine and obtain acceptance of the science among domestic and national regulators. This was assisted by the project becoming a standing item on the SDQMA agenda in July 2020 following request from the PHC, with the focus on achieving domestic and national acceptance of project outputs.

Cherries (produced in NSW and Victoria)

The cherry case study was jointly led by NSW DPI and Ag Victoria, with science input provided by CSIRO. A systems approach protocol was developed and refined for Queensland Fruit Fly (QFF) and Lesser QFF (LQFF). Trial trade negotiated with WA and South Australia played an important role in testing and refining the underpinning science, and its communication through a Data Package. Over 17,000 t of cherries were produced under the systems approach with no infested fruit detected in protocol orchards. Over 70 commercial consignments totaling over 1000t of cherries prepared under the protocol were traded to SA and WA with no infestations detected post movement. A comprehensive data package was written that evaluates the efficacy of the measures outlined in the systems approach protocol. This data package is already serving as a template for other protocol data packages (such as citrus, ICA21 and protected cropping), and also provided a mechanism for testing and socializing the underpinning science with key trading partners and DAWE. The cherry protocol and data package were presented to DAWE in March 2022 for endorsement and arecurrently awaiting technical advice being sought from the Australian Fruit Fly Technical Advisory Committee (AFTAC) before national endorsement as an Interstate Certification Assurance (ICA) protocol by SDQMA. There is strong demand in the cherry industry to have the cherry PSA ICA endorsed and accepted.

Exported cherries are currently mostly fumigated, but to manage reputational risks the industry is still keen to ensure that even dead larvae are not found in exported fruit. On request from Cherry Growers Australia (CGA), CSIRO met virtually with all cherry exporters prior to the 21-22 season to discuss with growers what needed to be done to minimize the risk of that occurring. PRReSTo was used, together with data collected throughout the project, to estimate risk of infested fruit being at detectable levels. This showed that infestation risk is exceedingly low for most growers. However, growers in warmer climates would benefit from monitoring, and corrective actions where flies are detected. This demonstrates how work from this project can be applied more broadly to help ensure “clean fruit” enters the supply chain even where post-harvest treatments are being applied.

Berries (produced in Victoria)

A Berry case study was led and run by Ag Victoria. It included field trials in Rubus (raspberry and blackberry) and strawberry crops. The same core set of measures as for cherries were applied, with refinements made to tailor the protocols to the crops’ production methods as the trials progressed. Pest abundance was shown to be very low in Rubus and strawberry producing properties within the Yarra Valley, with no infested fruit detected in consignments or from growth room assays conducted by Ag Victoria Research. Furthermore, laboratory tests found Rubus and strawberries to be poor hosts when compared to apricots. As further refinements and testing was needed to strengthen the berry protocols to address any late season risk, the development of a PSA ICA protocol was not considered possible within the timeframe of Ag Victoria’s participation in the national project, and was not progressed further. Future development of an ICA would need to consider the main growing regions for Rubus and strawberries, which would include the more QFF-favorable climatic conditions of Queensland and New South Wales. Any protocol would also need to take into account unique features of production, such as continuous picking through an extended season, direct packing during harvest and being grown on canes (for Rubus) which makes use of bait sprays more challenging.

Citrus (produced in NSW)

The Riverina citrus case study was led by NSW DPI and included monitoring, inspection and growth room research by NSW DPI, and modelling of trap density and crop scouting by CSIRO. Many of the contemporary learnings from the research and negotiation of the citrus and cherry PSA protocols were immediately and mutually applied, as the cherry season PSA results (September to January) preceded the citrus season (May to October). For the life of the project NSW was monitoring for nine months of each year, and heavily engaged in industry and interstate trade discussions for the balance of the year. A PSA protocol for QFF and LQFF was developed, and 15 consignments of trial trade occurred to SA and WA. Citrus is a winter ripening fruit, which is likely to only become susceptible to QFF and LQFF from cell expansion to color break in the Autumn when fruit flies are becoming inactive. Modelling of historical data from 2002 to 2015 suggested the measure of limited phenological overlap, or 'winter window', from May to October each year, when QFF detections were repeatedly low. Observations during the project (2016-2021) supported a winter window as a measure, but the winter window required a higher trap density to ensure pest prevalence was monitored at the block level, and that thresholds for corrective action with bait spray, and suspension, protected the winter window status of the block. A review of the efficacy of bait spray in controlling monitored pest pressure for the period 2012-2015 established that bait sprays were partially effective after at least two consecutive treatments, as long as Autumn pest pressure was low. Larval survival in citrus is known to range from low to very low. Growth room data from collected first grade, second grade, and fallen fruit during high pest pressure in 2020 supported that only fallen fruit were infested with QFF, and only at monitored pest levels above the proposed suspension threshold. Over 15t of citrus was inspected post entry and no infestations with fruit fly were detected. A preliminary assessment of the data compiled during the project indicates that the monitoring period should commence in April (rather than May) to ensure that the pest pressure is monitored during color change. Also if pest pressure exceeds the corrective action threshold in Autumn then a bait-spray should be applied while QFF are still active and feeding, otherwise a high overwintering pest population could result in suspension thresholds in the early Spring. While the winter window systems approach appears to have merit, particularly within QFF pest free area outbreak areas where citrus growers may deliver to a packhouse beyond the outbreak area, there is insufficient industry demand, and the PSA was not supported by Citrus Australia to be developed into an ICA. If a viable protocol is to be developed for domestic and international trade, Citrus Australia must be open to options beyond the existing cold treatment protocol, and the work needs to be nationally relevant.

Apples (produced in Western Australia)

The apple industry in Australia and Western Australia, are seeking to expand international exports to prevent saturation of the domestic market. In Western Australia, cold treatment data packages are available for medfly in Pink Lady® and Bravo™ varieties. The priority for this case study was to determine efficacy of several phytosanitary measures along a production pathway as part of a systems approach. Efficacy of the measures was determined via data collection through extensive lure-based trapping, apple cutting, in-field orchard inspections, degree-day modelling and other experiments.

Trapping aimed to improve the understanding and prevalence of two very closely related moths, Western Fruit Moth (WFM) and Light Brown Apple Moth (LBAM), and to establish baseline risk of medfly prior to end point treatment. Additional trapping was conducted for Codling moth and Queensland fruit fly (QFF) in apple growing regions and provided additional support to the long-term trapping grid run by WA DPIRD that Western Australia is free of both pests.

WFM and LBAM were both seasonally common in apple regions, with WFM most common in cooler areas (Manjimup and Pemberton) and LBAM more common in the Perth Hills. Larvae of both species can feed on foliage and externally on apples, with damage to apples readily spotted visually. No moth larvae were found during visual surveys of 172,800 apples that coincided with apple harvest. This suggests that infestation risk for both moth species in apples is very low.

Commercially available WFM and LBAM lures were field tested to assess their specificity, with identification of captured moths being confirmed through genetic barcoding. Initial results suggest that each lure type attracts both species but are much more effective at catching their target species.

Medfly trapping using female lures was conducted across major apple growing areas in Donnybrook, Manjimup, Pemberton and their associated towns, as well in the Perth Hills. Peak fly abundance varied between years and regions with seasonal peaks typically occurring from March to May, which overlaps with the period when apples are susceptible. Medfly were least abundant in Pemberton, and abundance was much lower in orchards than towns, even where orchards were close to towns. This supports other studies that medfly are poor natural dispersers and suggests that they are being well-managed in commercial orchards. Visual surveys of 172,800 apples in 2021 over 16 commercial apple orchards did not detect any medfly damage. By contrast, medfly was detected in citrus fruit from an orchard in Gingin, collected as part of this study.

Fruit cutting and rear-out of potential infestations of high risk-fruits (packhouse seconds or windfall fruits) was also collected from orchards with varying pest densities. In total 13,645 fruit were cut with 1,300 fruit set up for rearing out of potential infestations. Fruit cutting found no Medfly, LBAM or WFM though 0.28% of fruits contained possible old Medfly infestations. Rear-out detected no LBAM, WFM or Medfly in apples suggesting that infestation in commercial orchards is very low.

Various types of male and female lures are available for medflies. We compared a commonly used male lure/trap combination to a commonly used female lure/trap combination across two years in areas with differing pest densities to establish their relative efficacy. Both trap types caught about six times as many flies of their target sex and male-targeted lures caught 14% more medfly overall. Each lure provides different sensitivities in medfly detection, with female-targeted traps proving more efficacious in late spring to early Summer (c November-February). In Autumn (c March-May) both traps were efficacious. In winter (c June-July) male-targeted traps are more efficacious, as males disperse to find overwintering sites. A combination of both male and female trapping is therefore recommended for orchard management.

Western Australian apple orchards, although free of QFF and CM have significant hurdles to overcome to achieve market access through a systems approach. This is primarily due to the prevalence of medfly in the main apple production area, leaving growers with the options of creating areas of low pest prevalence through suppression of medly, or place of production freedom under ISPM 10. Current trapping results indicate that 5 properties assessed within this study were medfly-free and >7.5km from town centers. If place of production freedom is achieved, standard management practices combined with regular orchard inspections should be enough to prove absence of Epiphyas moths, but further control options may need to be implemented. Further research needs to be undertaken on Epiphyas moths in WA to fully determine the risks posed to orchards. Furthermore, research on the effects of key components of a systems approach on pests need to be quantified.

<u>Application to current regulatory issues</u>

The risk tool kit was applied to a range of regulatory issues that become topical during the term of the project. This provided a further mechanism for gaining acceptance and adoption of these approaches among regulators. Examples include:

- Participation in the ICA-21 Working Group initiated by the Plant Health Committee to review the efficacy of measures within the existing systems-approach protocol. PRReSTo was used to assess their combined effect to support continued acceptance for blueberries under ICA21, and to identify ways in which the protocol could be strengthened for stone-fruit and blueberries.
- Assisting South Australian Government in finding a solution to movement of fruit from suspension zones within the QFF Riverlands Pest Free Area in situations when there is no access to packhouses within the suspension zone.
- Negotiation of two market access arrangements between industry and WA for Tomato Yellow Leaf Curl Virus (TYLCv) and its vector Silverleaf Whitefly using outputs from the project. These auditable protocols removed the requirement for a NSW authorised officer to inspect and certify 22 consignments totaling 8 tonnes of tomatoes per month for one business and promoted the movement of almost 3000 seedlings from another business. These protocols have since been removed from use as WA accepts NSW's TYLCv freedom.
- Application of the principles developed in this project to review movement controls for Red Imported Fire Ant (RIFA) in 2020, which identified where existing entry requirements could be strengthened or simplified. Separately, NSW DPI also assisted QDAF to simplify ICA39 (inspection and chemical application to manage RIFA risk from nursery product movement) using the projects' PSA principles. The simplification was due to the reported efficacy of the treatment, and the removal of measures from the ICA39 protocol which were not reducing risk.
- NSW broadened the scope of the ICA57 national protocol saving the issue of over 300 Plant health Certificates (PHCs) in NSW a year. This change allowed for repacking and recognising produce under secure conditions

certified by an Import Phytosanitary Certificate, and allowed repacking certified melon thrips host produce which had been treated by methyl bromide for the control of QFF on QFF host produce. This process previously required a separate 'inspection and found free' PHC.

- NSW DPI negotiated permits to Tas and SA removing the need for 260 PHCs/yr for sliced and bagged apples for a major food chain. Fundamental to the success of the negotiations was the PSA argument to accept the risk reduction measures of reduce infestation rates by processing, and reduce establishment risks as the processed apples remain in sealed, transparent plastic packaging allowing inspection before opening.

Deliverable #4. Identifying and addressing barriers to adoption of systems approaches.

The assessment of institutional and economic factors influencing acceptance of PSA in domestic and international markets was achieved through:

- Deep engagement with cherry, citrus, berry and apple growers and packhouses through regular field visits and consultation, particularly between 2018-2020 which provided valuable, grassroots insights regarding the potential benefits/interests and barriers around use of phytosanitary systems approaches.
- Informal review of key institutional and governance arrangements for biosecurity and market access, and where there were opportunities to improve the availability of sound scientific evidence to inform decision making around risk management.
- Regular engagement with biosecurity regulators and industry organisations and committees, increasing through 2020-2022, to gauge concerns, systemic constraints and potential solutions

Critical constraints for use of PSA-based pathways identified through engagement with growers, industry organisations, state regulators and DAWE included:

- Perceived practical challenges and costs of maintaining multiple measures through the production/packing process
- Complexities and costs for regulatory oversight to verify/inspect implementation of multiple measures
- Difficulty of quantifying the risk reduction achieved by the combination of measures in a system
- Experience of trading partners being reticent to accept PSA, linked in part to a lack of confidence in their efficacy. However, this view was contradicted by risk scientists working in market access from countries such as the USA, South Africa and New Zealand.
- Concern by industry and regulators that negotiating PSA may be more challenging than end point treatments, thereby adding further risk to the already lengthy process of technical market access negotiations.

Key strategies progressed through the project to address these perceived constraints include:

- Development of a comparative costing model to assess and compare the costs of implementing a PSA with other market access pathways (detailed below).
- Establishing the basis for equivalence between authorised officers accepted for monitoring, crop and packed product inspection for exports (a DAWE responsibility) and the need for an approved and independent authorised officer to conduct similar functions for domestic trade (a state and industry responsibility). Current parallel processes result in costly duplication of the training, accreditation and audit of on-farm monitoring and compliance activities. Under the cherry and citrus case studies we tested the implementation of an authorised officer arrangement, modelled on training, accreditation and audit systems applied by DAWE for international exports, for verification of monitoring and inspection measures (fruit fly trapping and crop inspection) within the cherry and citrus protocol for domestic market access. Essentially, authorised officers accredited in the current season for exports automatically meet the domestic requirement. The project underwrites the ongoing discussion to support equivalence between DAWE and the Subcommittee for Domestic Quarantine and Market Access. We have drafted a discussion paper for regulators which compares the requirements for exports vs

domestic trade, and the findings of the citrus and cherry case studies to support an expanded acceptance of equivalence in similar export/ICA protocols.

- Development and testing of analytic tools and visualization methods as well as an improved template for data packages of supporting evidence for proposed protocols. This enabled proponents to present clear and quantified evidence of risk reduction from a proposed PSA.
- Development of an annotated menu of measures that provides clear guidance on measures that can be selected, the evidence needed to give confidence in how effective they are, and how to demonstrate compliance.

Comparative costing model

It is important that protocols are not only effective at managing pest risk, but are also least trade restrictive and cost effective. A preliminary costing model was developed to allow for a comparison of costs ($, time to market, avoided costs) of regulatory, logistics and treatment steps between PSA and existing phytosanitary protocols (methyl bromide fumigation and irradiation), using cherries as a case study. Costing estimates for protocol elements such as trapping, application of corrective actions, crop inspection, fruit inspection and end-point treatments were obtained from the literature and producers. Costings can also be entered by users to reflect their own experience. Although only a prototype, the comparative costing model was important in showing that the proposed PSA was cost effective, provided authorised officers could be used for monitoring traps and crop inspections. Additional work is needed if this tool is to be widely applied, including to account for indirect protocol costs such as effect on quality and time to market. Confirmation of industry and regulatory demand for this tool would be needed to pursue it further.

Outcomes and insights

- The comparative costing model offered a useful first step towards addressing concerns regarding the costs of implementing PSA. The model improved transparency and enabled the comparative costs of various pathways to be assessed. Stakeholder feedback indicates there would be significant value in further developing the model to incorporate a wider scope of costs and benefits, for example to estimate the enhanced returns possible from delivering a more premium quality product to market in a shorter time (if the quality and logistics impacts of fumigation were avoided). Feedback also identified the model could provide the basis for a tool that demonstrates the value of proactive on-farm biosecurity measures.
- As a result of their participation in the research, the apple, cherry and berry industries have a stronger willingness to pursue a PSA pathway where there is a clear fit with their technical market access strategies. They also have greater confidence that rigorous analytical tools are available to prepare the required supporting evidence. Through extensive engagement activities, the project has communicated the availability of the tools across the horticulture sector.
- While the project set out to develop improved scientific methods to demonstrate the efficacy of formal PSA protocols, the methods can be used to prepare supporting evidence for a wide range of market access pathways. There are significant opportunities to apply a PSA – in the broader sense – to better leverage existing risk reducing practices throughout the production process. Not all measures need to be mandated and auditable within a protocol, but could be recognized within the pest risk assessment process, or implemented to meet commercial/market standards. These prospects are explored in more detail in van Klinken et al. (subm.).
- Overall, the project has improved the confidence of biosecurity stakeholders in PSA. As a result of the research, there has been a discernable shift in willingness across industry and government to consider systems approaches, linked to the availability of improved tools to assess and quantify risk and risk management measures.

Deliverable #5. A Systems Implementation Plan for industry

An online resource centre for systems approaches was agreed by project partners to be the most effective mechanism to support implementation and uptake across the horticulture sector. A PSA website was developed as a CSIRO research page and launched in May 2021 to facilitate access to the project's information and tools. The site establishes an on-going portal for long term and universal access to the resources created through the project. The site will be maintained by

CSIRO, and resources will continue to be posted as they are developed and refined following the completion of this project. The long-term aim is for the portal to become established as a primary reference site across the international phytosanitary and technical market access researcher, regulator and practitioner community, and to help facilitate harmonization of methods and approaches.

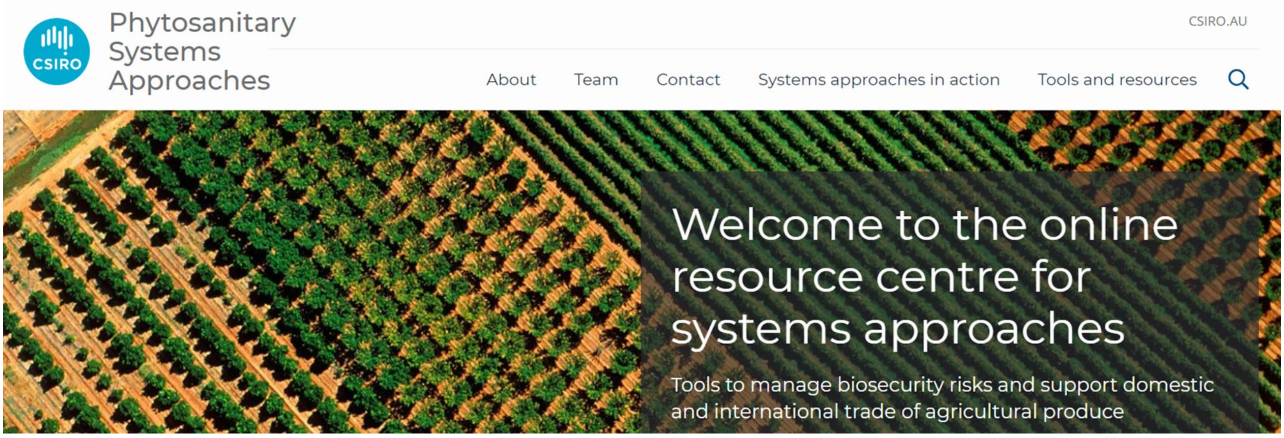

Figure 6. A screenshot of the online resource centre https://research.csiro.au/psa/

The online resource centre provides access to:

- Contextual information around agricultural trade and the need to manage associated biosecurity risks
- Background information on market access pathways used to manage trade-related biosecurity risks, including PSA
- The rationale and intent of the systems approach research project, and investment provided by project partners and Hort Innovation
- Potential benefits of PSA and circumstances where they may offer a useful option for industry to achieve market access
- Available tools to guide phytosanitary risk management and prepare supporting evidence for market access protocols, currently
    - The phytosanitary risk management framework
    - A menu and technical manual for phytosanitary measures
    - A sampling calculator for crop and consignment inspections
    - PRReSTo – the pest risk reduction scenario modelling and evaluation tool
- A road map of the process for developing a PSA protocol, highlighting the tools developed through the project and where they are applied.

Over the final months of the project, the project team determined that the website should be re-framed, to reflect the broader applicability of the tools to research and analysis for all market access pathways and wider trade-related biosecurity challenges such as the design of movement controls to manage new plant pest incursions or outbreaks in declared pest free areas. Updates to the website name, framing and content will be implemented in June-July 2022 to ensure that the portal engages a wider audience of horticulture industry and biosecurity stakeholders.

To provide more specific guidance for each case study industry, short road map documents have been prepared. These summarise the data sets and analysis generated through the project, and indicate how these may contribute to the industry's domestic and international market access aims, including the most likely prospects for the use of systems approach pathways. The road maps also identify priorities for future research.

Deliverable #6. Communication to achieve wide acceptance.

A strong emphasis on communication and engagement with key stakeholders has been integral to the success of this research project. The project communication plan identified core stakeholders as the Commonwealth Government, Australian state regulators, horticulture industries, and the international science community. At the project's inception, understanding of PSA was somewhat limited across all of these stakeholders and the lack of rigorous scientific methods to validate the efficacy of combined phytosanitary measures posed a significant barrier to acceptance. The project team has used a range of engagement strategies to build awareness of the research and its case studies and to demonstrate, and establish confidence in, the tool kit for phytosanitary risk assessment and management developed through the project. Written publications are outlined in the outputs section of this report. The online resource centre for PSA, described in Deliverable #5, is another core communication strategy that will enable stakeholders to continue to access and engage with the outputs from the research beyond the life of the project. A summary of direct stakeholder engagement activities is outlined below.

Overall, across the life of the project, three journal papers have been published, one submitted and a further five are in late draft stage; ten presentations have been delivered at national conferences and webinars; and over forty presentations and workshops have been delivered in industry and government stakeholder forums. The project team has also participated in and presented to four international workshops to socialize the research with scientists who have an influence with Australia's key trading partners.

<u>Commonwealth Government</u>

Establishing a strong working relationship with key personnel in DAWE was a core priority for the project team, as the support of the department is required to pursue international market access for horticulture that is based on PSA. Departmental representatives were active and valued participants in project governance committees and the project leader closely liaised with DAWE senior staff through regular conversations, meetings, presentations and workshops. Engagement with the department provided clarity around the interests, constraints and opportunities for the greater use of PSA for international market access and helped define the scientific methods gaps the research could help to address. Efforts were made to closely align the research with the department's strategic direction. As the research progressed, concepts, methods, tools, resources and graphics, were shared with DAWE for their review and feedback. In particular, the project sought and received DAWE's endorsement of key resources, such as the menu of measures technical manual, to help establish agreed core reference documents for domestic biosecurity stakeholders. In the final stages of the project, DAWE technical panels have been established to review draft manuscripts prior to their submission for scientific peer review and publication. The project team liaised closely with DAWE in the development of the cherry data package, including seeking DAWE's review of the package prior to submission to SDQMA. This process has helped DAWE to demonstrate to state jurisdictions the standard of evidence desired for inter-state trade arrangements. DAWE's engagement in the research has helped to improve the confidence and enthusiasm of departmental staff that PSA can be developed with rigorous supporting evidence. An indication of the project's positive impact was an internal symposium in November 2021 involving multiple teams within DAWE to discuss the opportunities to progress PSA and to apply systems thinking and the tools generated through the project to support the assessment and management of phytosanitary risks across many areas of the department. DAWE has subsequently invested in a partnership project with CSIRO to drive the consistent implementation of risk science and systems principles, terminology and methods within the department.

<u>Australian state government regulators and national biosecurity agencies</u>

The project maintained a strong focus on engagement with state and territory governments as they hold core responsibilities for managing biosecurity risks related to the inter-state movement of horticulture produce. The project established links to national biosecurity bodies through regular briefings, presentations or discussions with the Plant Health Committee and its subcommittees, as well as Plant Health Australia. The working relationship with the Plant Health Australia team has been particularly valuable and helped to shape the evolution of thinking over the life of the project. From July 2020, the SDQMA included a project update as a standing agenda item at its meetings, in recognition of the strategic value of the research for rigorously addressing trade-related biosecurity risks. The project was invited to deliver a workshop for the SDQMA in April 2021 to engage committee members in the risk framework and menu of phytosanitary measures and demonstrate how they can be applied to guide biosecurity decision making. An indication of the project's positive impact was the request from an SDQMA working group to contribute to the review of ICA21, in particular, to apply the PReSSToO model to assess the best options to strengthen the entry condition requirements. The project team communicated regularly with the chief plant protection officers and biosecurity and market access teams in each state/territory. An important stage of the engagement process was a series of meetings held throughout 2021 to brief each state biosecurity team about the supporting data package for the cherry protocol prior to its consideration at SDQMA. These briefings provided a practical demonstration of how the project had supported the rigorous development and testing of an inter-state trade protocol and made a significant contribution to building understanding and confidence amongst state government biosecurity personnel in the underpinning risk science methods and analytics tools developed through the research. State government biosecurity and market access personnel have provided positive feedback on the cherry data package and the emerging phytosanitary risk management science tool kit, with constructive discussions around how the tools can be applied to assist their work. Through their engagement with the project, there are clear indications that state biosecurity regulators are more willing to accept PSA with robust supporting evidence and are motivated to review and refine established PSA-based inter-state trade arrangements that are not managing biosecurity risks sufficiently. The widespread support from state agencies to participate in a follow-on research project aimed at applying the tools to improve domestic market access arrangements is a good indication of the positive impact of this project.

Horticulture sector

The project has engaged with horticulture industry stakeholders from grassroots through to strategic levels. From the foundation phase of the project, the team have invested in building strong connections with growers, packhouses and wider industry networks involved in the apple, cherry, berry and citrus case studies, led by the state government delivery partners and supported by the project engagement coordinator. This enabled valuable two-way communication between the project and industry partners and, importantly, provided the opportunity for the research to be responsive to concerns and interests raised by industry members. The frank dialogue and trust established with industry through the project informed a rich understanding of the practical challenges of implementing PSA as well as both the barriers and prospects for pursuing these as market access pathways. Industry feedback was critical to inform the development of the comparative costing model and also guided work on the other models and tools. In the later stages of the project, there was an increased emphasis on engagement with peak industry bodies. The project team has met with peak groups representing the case study industries, and additionally with vegetables, melons, avocados, stonefruit, protected cropping, and the Australian Fresh Produce Alliance. Discussions addressed progress through the research to improve the underpinning scientific methods for phytosanitary risk management, technical market access strategies for the commodities, and consideration for where PSA have best potential to contribute to market development aims. Links were also established with a wider set of players in the horticulture supply chain, including national retailers, service providers and the ag-tech sector. Presentations were made to a wide range of horticulture industry conferences and national horticulture industry representative groups, including HEICC and the Hort Innovation ITAP, to communicate the strategic importance of the research and the potential applications of the risk science tools for the industry. At the close of the project, there is a higher level of awareness of PSA as a viable market access pathway amongst horticulture industry stakeholders as well as a growing recognition that the science tools can be applied to support all market access pathways, including to define how additional measures in the management system can contribute to improved confidence for treatment-based pathways. The apple, cherry and berry industries have identified specific international markets where PSA pathways should be developed.

National and international science community and technical market access community

Engagement with the science community and specialists in the technical market access field is essential to raise awareness and support for the research amongst stakeholders who influence methodological and empirical standards, the setting of guidance materials for the regulation of international trade, and the preparation of supporting evidence for market access negotiations. Engagements aimed to communicate progress towards advancing the methods and tools for PSA and phytosanitary risk management and encourage acceptance and adoption. The project team participated in strategic meetings and workshops of international researchers, in particular:

- ASEAN forum Singapore in July 2019
- FAO Phytosanitary Measures research group meeting in Cairns, September 2019, that included representatives from South Africa, New Zealand and China
- Australia-Korea Science Symposium in December 2019
- Imperial College (London) collaborative workshops, October 2019 and May 2020

The team also presented at multiple national conferences, symposiums, webinars and a South Korean trade delegation to socialise the research with a wide network of national and international scientists and biosecurity specialists. This engagement has generated considerable international interest, and this work is now seen as world-leading, as confirmed by direct feedback from international collaborators, and from third parties.

Outputs

A high-level summary of project outputs is listed here. Where necessary further details have been provided directly to Hort Innovation, including a log of extension activities, data generated through the project, and journal articles that are being prepared for publication.

Table 1. Output summary.

Output	Description	Detail
Phytosanitary Systems Approach online resource centre	Website to provide a portal to phytosanitary risk management science tools for horticulture industries and for national and international biosecurity stakeholders.	https://research.csiro.au/psa/ The website provides on-going, universal access to the principles, methods, tools and resources developed through the project, and enables horticulture industries to consider how the tools can be applied to advance technical market access solutions, including systems approaches, for target markets, both domestic and international. Further tools and resources will be added to the site as they are finalised and as peer-reviewed journal articles are published.
Phytosanitary Risk Reduction Framework	Sets out how trade-related phytosanitary risks can be mitigated through one of four risk reduction objectives applied in three consignment stages.	Published (van Klinken et al. 2020, subm.) and available online https://research.csiro.au/psa/tools-and-resources/systems-approaches/ The framework underpins all other phytosanitary risk modelling and analytical tools and resources developed through the project. The acceptance of this foundation methodology by Australian biosecurity regulators is shown by the strong interest by DAWE and state governments to participate in proposed follow-on investments.
Menu of phytosanitary measures – technical manual / guidelines	Identifies from international literature review, 39 distinct ways (measures) that risk can be reduced, grouped under 10 measure categories within the risk framework.	Guidelines available online https://research.csiro.au/psa/ supported by a journal paper (van Klinken et al. subm) Engagement with government and industry stakeholders indicates a high level of interest in the menu and guidelines.
PRReSTo (Pest Risk Reduction Scenario Tool)	PRReSTo is a tool that allows users to estimate pest infestation rates in consignments and to quantitatively compare the risk-reducing effect of one or more measures.	The tool can be run through a commercial software package (Netica). CSIRO has also prototyped a simple web interface that will be made available through the online resource centre when finalized. This will enable the scenario modelling tool to be accessed and used independently by biosecurity practitioners. A peer-review publication describing the model is in preparation (Froese et al. in preparation). The model underpinned the analysis for the cherry data package. Acceptance and use is also evidenced by diverse applications, including to inform a review of ICA21, as requested by the SDQMA working group.
Inspection sampling tool	A web-based sampling tool allows users to quantify and compare the benefits of different fruit sampling strategies. That includes inspected packed fruit, fruit from reject bins and crop inspection.	This tool is available online (https://research.csiro.au/psa/). This tool helped support the inclusion of crop inspection as a valuable measure in the cherry systems approach. It has also helped regulators design more effective protocols.
Surveillance design	A model was developed to evaluate detection	Most work on surveillance design has focused on requirements for pest free areas. This new model focusses on block-based

model	probabilities of different trap arrangements, and hence guide the optimal placement of traps for block-based surveillance.	surveillance design. This work informed the design of the systems approach cherry protocol. It has also played an important role in giving regulators greater confidence in the design and use of block-based surveillance as an entry requirement. The modelling methodology is being prepared for publication (Hill et al. in prep).
A suite of coding functions (in R) for synthesis and analysis of surveillance data	Code that couples observations (trapping data) with phenology (development models) and climate data to return concise and informative overviews of regional- and orchard-level pest pressure.	This code was used to generate results used in data packages prepared in this project. Code is written that it is reusable, and readily extended to other pests and situations. Considerable surveillance data is collected to meet entry requirements. This code is an important step towards allowing that data to be also used to generate valuable insights for industry and regulators.
Method for evaluating protocol efficacy from compliance data	A statistical methodology to quantitatively estimate confidence in the trade protocols through analysis of surveillance and fruit inspection data.	This method has been applied to give confidence in efficacy of cherry systems approach, and is being utilized to demonstrate benefits of pre-harvest surveillance and of multiple fruit inspections. A manuscript describing the methodology is close to submission (Caley et al. in preparation).
Comparative costing tool	Comparative cost calculator (prototype) to compare costs (per tonne or hectare) of implementing different protocols.	This is available on request as an Excel spreadsheet. Historical or user-defined costings can be used. This tool played an important role in demonstrating the importance of establishing an authorized officer model for trap surveillance and crop inspections.
Cherry systems approach protocol and data package	A draft systems approach ICA for cherries, operational procedures for NSW (CA19) and Victoria (PS41), and a supporting data package.	Both were submitted to the SDQMA for review in March 2022 and will updated and finalized pending feedback and a decision. Aspects of the cherry data package will be made available through publication.
Horticulture industry implementation road maps	Brief summary documents for case study industries outlining opportunities to apply the data and tools from the project to improve market access, including through PSA pathways	Opportunities to pursue PSA pathways and, more broadly, to apply the data and tools generated through the project to support improved market access have been discussed with peak industry bodies for apples, berries, cherries and citrus. Brief summary road maps outlining priority opportunities will be shared directly with peak industry groups and could also be considered by Hort Innovation and its strategic investment advisory panels.
A draft plan to recognize the equivalence of cherry and citrus crop monitors for export and domestic trade to manage the quarantine risk, simplify audits, and save industry money.	A draft discussion paper for regulators which compares the requirements for exports vs domestic trade (cherry and citrus PSA), to support an expanded acceptance of equivalence in similar export/ICA protocols.	Current parallel processes between authorised crop monitors for exports (a DAWE responsibility) and government authorised officers for domestic trade (a state and territory responsibility) results in costly duplication. Allowing already authorised export crop monitors to conduct trap and crop monitoring for domestic trade saves a business $3000/yr. Recognising that a business has an equivalent training, accreditation, audit and results reporting authorized crop monitor is reported to save a business $100,000 a year in duplicated administration, as a dedicated position is required. This draft plan is prepared to support the DAWE Busting Congestion Project as a workplan priority for SDQMA on seeking greater equivalence in export/domestic protocol implementation.
Citrus protocol and	CA15 domestic trade	This work was conducted collaboratively with NSW citrus

data package	procedure for Winter citrus, and a draft supporting data package	growers. It is available for use in NSW if sufficient demand arises, and if permits from QFF sensitive jurisdictions can be secured. It has been shared and discussed with jurisdictions who are experiencing outbreaks in QFF pest free areas.
Data package to support systems approach for medfly in West Australian apples	A draft systems approach for the apple industry in Western Australia with a supporting data package.	A set of phytosanitary measures were developed and evaluated to mitigate the risk of significant pests of quarantine concern being present in export apples from Donnybrook, Manjimup, and Pemberton. Measures included area freedom from Qfly and Codling moth, area of low pest prevalence for medfly and *Epiphyas* sp., trapping, pest avoidance (harvesting in a period when fruitfly and moths are absent) and quality grading.
Apple case study- Mediterranean fruit fly	A case study, quantifying relative risk of medfly in apple orchards in WA to determine what this means for a SA.	This work was conducted collaboratively with WA apple growers through Pomewest. This case study demonstrates relative risk of medfly to the pomefruit growers of WA through intensive field surveillance of medfly, apple cutting, infield orchard inspections and other trials. From this data we identified key areas that could be eligible to apply for place of production freedom under current medfly distribution.
Apple case study- *Epiphyas* moths	A case study, quantifying relative risk of *Epiphyas* moths in apple orchards in WA to determine what this means for a SA.	This work was conducted collaboratively with WA apple growers through Pomewest. This case study demonstrates relative risk of *Epiphyas* moths to the pomefruit growers of WA through intensive field surveillance of *Epiphyas* moths, apple cutting, infield orchard inspections and other trials. From this data we identified key areas that could be eligible to This data indicates the populations of *Epiphyas* moths are low, and risk is low under standard management.
Apple case study, - a snapshot of the national and international pome fruit industry	An overview of the market access opportunities for apples and details of national and international apple production	A literature review that summarizes apple production, market access opportunities. With details on how to gain access to those markets via different measures and requirements.
Berries draft protocol and report	Operational Procedure (PS-47) outlining the requirements for a systems approach for QFF management in berries for trade from Victoria to WA and SA, and associated case study report.	This work was conducted collaboratively with berry growers in the Yarra Valley. No QFF were detected in fruit grown under the trial protocol. However, national demand would need to be confirmed, and research extended areas with higher pest densities, for it to be into converted into an ICA.
Curated data (2017-22)	Data collected through the project including trapping, brown sugar flotation, fruit inspection and fruit rear-out.	A complete, curated, data-set has been provided to Hort Innovation. This will be a valuable resource going forward for industry.

Outcomes

The project logic that has guided the delivery of the project is presented in Figure 7. Since inception, the project has broadened its end-of-project outcome from "*regulators and industry have confidence in quantitative systems approaches*" to "*systems approaches more readily accepted, and more effectively utilized, by industry and regulators through the application of science-based principles and tools.*" The outcomes achieved through the project are outlined in Table 2.

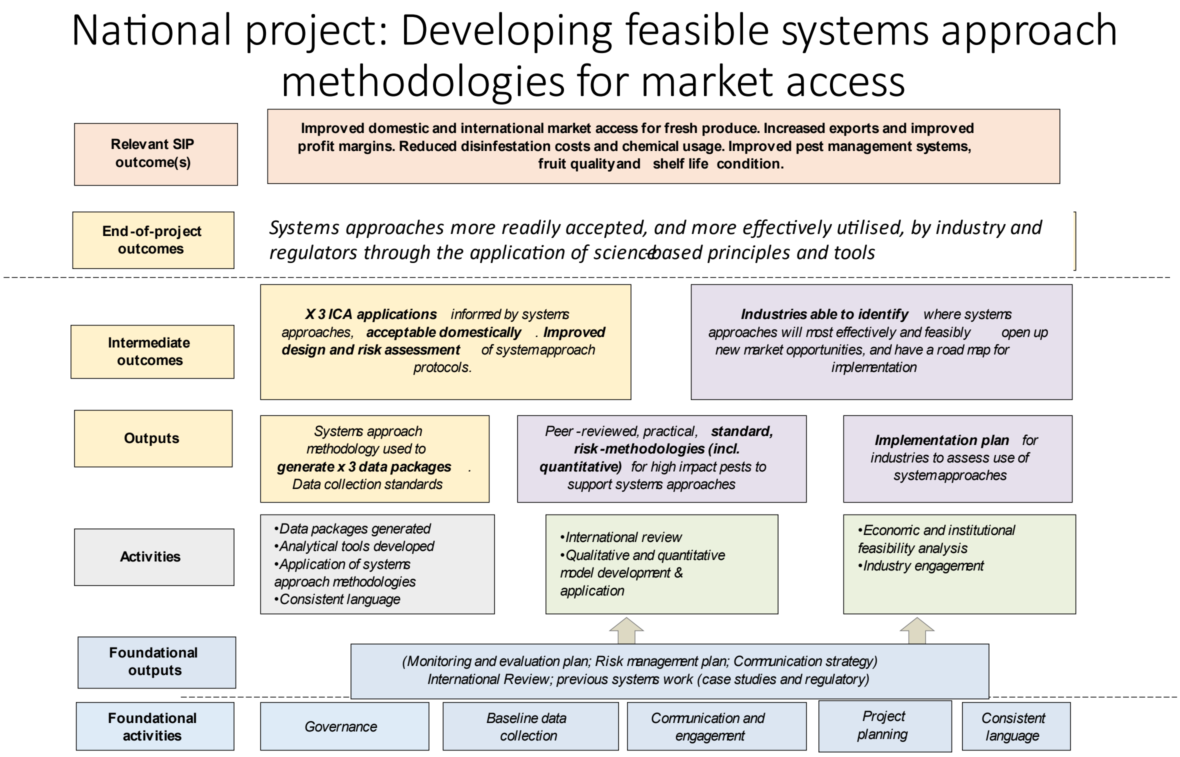

Figure 7. Project Logic developed for the project by the project team.

Table 2. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Improved acceptance and use of systems approaches by Australian biosecurity regulators, through the application of science-based principles and tools.	Improved domestic and international market access for fresh produce	Biosecurity regulators in Commonwealth and state governments have significantly higher confidence that systems approach market access protocols can be developed or refined with strong supporting evidence, following socialization and application of an improved risk science-based phytosanitary tool kit, developed through the	SDQMA working groups and state-based regulators have sought assistance through the project to apply the tools to help review/improve poorly performing systems approach protocols, refine inter-state trade regulations, and develop systems approach-based movement controls for horticulture produce from outbreak zones in PFAs. State/territory governments have committed to participate in a follow-on project to facilitate application of the tools to improve the domestic regulation of trade-related biosecurity risks, including the use of systems approaches where

		project.	appropriate. The proposed project was endorsed by the Plant Health Committee in March 2022 as being in the national-interest and highly aligned with the strategic priorities of the Plant Health Committee DAWE has committed to invest in a partnership project with CSIRO to facilitate application of the tools within the department, including a strategy to support the use of systems approaches for international market access.
Improved design and risk assessment of systems approach protocols leading to improved acceptance for use for domestic trade of horticulture produce.	Improved domestic and international market access for fresh produce. Reduced disinfestation costs and chemical usage. Improved pest management systems, fruit quality and shelf life.	The project has generated a suite of methods and tools that significantly advance the ability to design and rigorously test the efficacy of PSAs, and to refine existing protocols. An enhanced acceptance amongst biosecurity regulators has been facilitated through demonstration of trade under the trial PSA protocols for cherries and citrus to South Australia and Western Australia, with no breaches recorded, and the development of comprehensive data packages for the trial protocols. The cherry protocol and data package was submitted in April 2022 for endorsement by SDQMA, following review and endorsement by DAWE.	Feedback from DAWE and state regulators has been gathered through briefings/discussions of the cherry protocol and data package throughout 2021/22 as noted in engagement log. States have provided their individual feedback on the cherry protocol and data package through SDQMA. At the time of reporting, it is understood that the states have indicated general support for the protocol. As the cherry data package is considered to set a precedent and improved benchmark for supporting evidence for systems approach protocols it has been referred by SDQMA to the PHC Australian Fruit Fly Technical Advisory Subcommittee for further review.
Australian horticulture industries have a stronger understanding and acceptance of systems approaches, with road maps developed that outline opportunities where systems approach pathways could achieve improvement to existing markets or access to new markets.	Improved domestic and international market access for fresh produce. Reduced disinfestation costs and chemical usage. Improved pest management systems, fruit quality and shelf life.	Data gathering and analysis through the cherry, citrus, berry and apple case studies has demonstrated to the participating industries that robust and defensible systems approaches can be developed to improve market access. Strategic engagement with peak industry bodies have identified opportunities to develop systems approach pathways or apply the risk science tools to support wider technical market access efforts.	Industry feedback has been gathered through targeted workshops and meetings, and through participation in industry conferences and forums (see engagement log) The apple and cherry industry have indicated their interest to participate in a follow-on project, with the intent of applying systems approaches to protect and enhance international market access.

Monitoring and evaluation

A summary of overall project performance, and areas for continuous improvement, against Key Evaluation Questions developed by the project team during project initiation.

Table 3. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
Project team is high-performing: strategic not reactive; "sum is greater than the parts".	Strong teamwork, and a strategic focus, was developed and maintained throughout the project despite the inherent challenges of national, multi-organizational projects, and of working in an area that can be reactive to emerging regulatory challenges and industry needs. Project outputs and outcomes goals were met or exceeded, which would not have been possible without strong collaboration between researchers, regulators, policy makers and industry. The project team also successfully navigated evolutions in scientific understanding, and their policy implications.	Subcontracts with state government partners were always with a single part of the department whilst science, regulatory and market-growth capacity relevant to project outcomes are typically distributed across different parts of government. Broader engagement within state departments would have been beneficial, but likely would require more targeted effort and higher-level support within Departments to achieve.
Regulators have confidence in quantitative systems approaches, and the project teams ability to help deliver that. Are all jurisdictions actively engaged and is there progress towards agreed general systems approach methodology?	Strong support for the project and its outcomes were gained through the project, as evidenced through invitations to present or lead discussions at PHC, SDQMA and other forums. A risk tool kit was developed to support the use of systems approaches, and it is already being widely used by regulators. There is now commitment from PHC, DAWE and state/territory jurisdictions to use outputs from this project to continue to strengthen the risk science underpinning biosecurity and trade.	Now that the scientific foundations are well established, national benefits of this works could potentially be more quickly realized through a more formalized arrangement with national, state and territory regulators, through Plant Health Committee. The project would have benefited from surveys/interviews in the first and final years to collect data regarding the attitudes and practices of key stakeholders to enable a more rigorous assessment of the impact of the project on acceptance/confidence of PSA and impact/applications of the science tools.
Industry are making strategic decisions around use of systems approaches to expanding market access-opportunities: Industry are making evidence-based long-term investment decisions around development of PSAs	Industry participants have indicated their strong support to see the cherry PSA protocol endorsed as an ICA to enable its long-term use for inter-state trade. Technical market access advisors and export project coordinators from horticulture peak industry bodies (apples, cherries and berries) have actively engaged with the project team to secure future project investments to enable longer-term application of the data and risk science tools to help protect existing market pathways and to create new market opportunities. Engagement with leading horticulture companies and retailers has confirmed the risk science tools can be strategically applied to strengthen specific trade protocols/entry conditions and biosecurity risk management decision making,	Longer-term mechanisms should be considered to support horticulture industries to draw on the tools and insights from this project to help inform future technical market access planning processes, for domestic and international markets. There would also be value in facilitating greater alignment between this project's outcomes, industry market access efforts, Hort Innovation's international trade and market access investments, and state and Commonwealth government market access efforts. A workshop with key stakeholders may be a useful first step.

	more generally.	
Systems approach is founded on world-leading science, and there is a pathway to national and international scientific acceptance	The project team is now recognized globally as leading the scientific development of systems approaches. This has been achieved through peer-review publication in international journals, leading a systems approach forum at an international IPPC workshop, direct engagement with international risk scientists and invitations to present at relevant ASEAN forums and to trade delegations. Continued peer-review publication of project outputs will assist in gaining scientific acceptance.	A "post-covid" strategy is needed to increase international collaboration and acceptance. It would include a focus on other trading countries with an explicit interest and capacity around improving risk-based trade.

Recommendations

Research delivered through this project has broad applications, well beyond its primary focus on Phytosanitary Systems Approaches. Addressing the following priorities would help to maximize the benefits of this work for the Australian horticultural industry:

1. **Extending application of the risk tool kit developed in this project to the assessment and management of trade-related biosecurity risks**. For example, the Risk Framework and Menu of Measures can be used to help identify how risk can be managed across any trade pathway. Similarly, PRReSTo could be extended to quantify risk along diverse trade pathways, and to quantify how that risk could be managed through the application of one or more measures. Risk tools can also be used to support the recognition of commercial practices that can be demonstrated to reduce risk, but are not always recognized when entry requirements are set.
2. **Continue collaborative efforts with industry, domestic regulators and international regulators to embed the risk tools into practice.** There is already a strong commitment from DAWE, states/territories and the Plant Health Committee to ensure that this occurs, and project case studies have demonstrated the benefit of a collaborative approach. Consistent approaches to setting effective yet least-trade-restrictive entry requirements among domestic and federal jurisdictions will drive harmonization efforts, making it easier for industry to secure and access diverse markets.
3. **Support horticulture industries to harness the phytosanitary risk management science tool kit within their technical market access efforts.** A number of horticulture industries invest in the development of technical market access strategies that assess and prioritize target export markets and the potential pathways to address pests of quarantine concern in target markets. There is significant opportunity to facilitate the use of the toolkit in the assessment of pathway opportunities, identification of available supporting data and critical data gaps, and the design of research projects to develop specific market access protocols. The tools could also be usefully applied to evaluate and refine established protocols and build evidence to support market improvements.
4. **Support the development of new measures that are compatible with contemporary production systems and supply chains and which can be quantitatively evaluated for inclusion in market access pathways**. Our international review of measures identified a range of measures that are likely to be effective at reducing risk, yet are not often used. For example, grading is rarely formally recognized as a phytosanitary measure yet many production systems now use sophisticated optical grading technologies and require high fruit quality standards. Greater options in available measures will provide industry with greater versatility in how they manage quarantine pest risks.
5. **Application of our risk tool kit to help industry ensure that "clean" (pest free) fruit is entering the supply chain,** irrespective of subsequent treatments. For example, PRReSTo could be modified to quantify within-season quarantine risks across different growing regions and production practices. This in turn could be used to provide bespoke management recommendations to producers.
6. **Better use of data generated through production and the supply chain to help industry manage quarantine pests, and for regulators to maintain and improve market access**. Our project illustrated the valuable insights that can be generated from the vast amount of compliance data that is collected to meet entry requirements. However, to achieve this potential, greater focus is needed on the gathering of data, application of privacy-preserving analytics, and on providing actionable insights back to industry.

7. **Reduce the reliance on end point treatments by adopting a more explicit and dynamic risk-based approach.** End point treatments are a common option for managing pest risks as they can often be relatively easily implemented and verified. However, the required mortality rate imposed by an endpoint treatment is rarely calibrated to the risk it is intended to manage. Digital traceability systems, for example, would when combined with our risk tools, allow biosecurity risk to be estimated as produce passes through the supply chain. It could do so by accounting for exposure risk (through pest monitoring) and supply chain conditions (such as cold storage) and practices (such as grading) that might influence risk.

Refereed scientific publications

Journal articles

van Klinken, R., Fiedler, K., Kingham, L., Barbour, D., 2021. The importance of distinguishing between demonstrating the efficacy and implementation of phytosanitary systems approaches. Crop Protection 139: 105287 https://doi.org/10.1016/j.cropro.2020.105287

van Klinken, R. D., Fiedler, K., Kingham, L., Collins, K., Barbour, D., 2020. A risk framework for using systems approaches to manage horticultural biosecurity risks for market access. Crop Protection 129: 104994. doi:https://doi.org/10.1016/j.cropro.2019.104994

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