CLIMATE CHANGE ADAPTATION PROGRAM

Pest & Pollinator Gaps & Opportunities Assessment & Implementation Plan

Project Report

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Vancouver Island, British Columbia, 2021

Pest & Pollinator Gaps & Opportunities Assessment & Implementation Plan

Project Report

Vancouver Island — Pest & Pollinator Gaps & Opportunities Assessment & Implementation Plan: Project Report

Prepared by ***Pollinator Partnership Canada*** and ***Samantha Charlton Consulting*** under project V101 of the ***Regional Adaptation Program***, a program delivered by the ***Climate & Agriculture Initiative BC***.

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- Alberni Farmers' Institute
- BC Ministry of Agriculture, Food and Fisheries
- Capital Regional District
- Climate & Agriculture Initiative BC
- Comox Valley Farmers' Institute
- Comox Valley Regional District
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Executive Summary

With climate change, shifts in the distribution, lifecycles, and prevalence of agriculturally relevant pest, pollinator, and biocontrol species are anticipated. It is important that proactive agricultural adaptation occurs to mitigate impacts. Strategic adaptation will help reduce the vulnerability to these impacts while building capacity to adapt and respond, minimizing production losses and cost increases from changing pest pressures, pest management, and pollination in the Vancouver Island region (VIR).

The purpose of this project is to review and summarize current resources, monitoring activities, and research related to agriculturally relevant pests, pollinators, and pest control species in the VIR, including climate change considerations. Gaps, opportunities, and priorities are identified.

Three methods of information gathering were employed including internet searches and contractor knowledge, consultation with key stakeholders, and analyses of Ministry of Agriculture plant health lab sample history from the VIR. In total, input was received from 33 stakeholders. Interviewees included producers, provincial government, federal government, non-profit/non-governmental organizations, private consultants, and academic researchers.

Key gaps identified from the research and resource scan were 1. Pest Management: local research pertaining to biocontrol, biocontrol species identification resources, extension/grower knowledge on biocontrol, and treatment options for new/emerging pests, 2. Forage sector: there were gaps in VIR production and integrated pest management (IPM) guides, 3. Pollinators: there is little/no research on pollinator populations in relation to agriculture in the VIR or optimizing plantings. From the monitoring scan and stakeholder interviews, key monitoring gaps were identified with the largest gap being general, coordinated monitoring of pests and beneficial organisms in the VIR.

While many gaps were discussed by stakeholders, the main gaps that were frequently discussed were: lack of grower awareness of pest management resources, lack of extension to growers to support IPM and climate-resilience practices, lack of financial support for these practices, and a lack of monitoring and research in the VIR that would help inform baseline populations of pests and beneficials, new incursions, population changes, associations with landscapes and farm practices, efficacy of biocontrol practices in the VIR, cost-benefit analyses in the VIR, and habitat optimization for ecosystem service provision.

There are many opportunities for building on existing networks and communication channels, and creating new communication channels, in order to increase awareness of resources and support for climate-resilient agricultural practices. There are opportunities to bring existing financial support programs into the VIR and/or use programs that are already available in the VIR such as the Environmental Farm Plan (which currently is integrating more biodiversity/pollinator BMPs into the program). There are opportunities to partner with established groups in the VIR to address some of the gaps including government and non-governmental organizations, invasive species councils, and farmer organizations.

Implementation priorities, based on the research and resource scan, monitoring scan, and stakeholder interviews are outlined at the end of the report. Overall, the key gaps and implementation priorities identified from the body of information that was synthesized are:

- Increasing grower awareness and use of existing resources
- Increasing grower knowledge of and support for implementing climate change resiliency practices (new resources to fill gaps, communication networks, extension, financial support)
- Increasing knowledge specific to the VIR including baseline monitoring and field research

Proposed projects that address these implementation priorities are included for discussion.

1.0 Introduction

With climate change, shifts in the distribution, lifecycles, and prevalence of agriculturally relevant pest, pollinator, and biocontrol species are anticipated. Increasing annual temperatures – in particular winter minimums – are expected to magnify pest impacts and management complexity and costs. Extreme and variable weather conditions are likely to impact pollinator and beneficial species populations in the Vancouver Island region (VIR).

It is important that agricultural adaptation to a changing climate occurs before impacts become severe. Strategic adaptation will help reduce the vulnerability to these impacts while building capacity to adapt and respond, minimizing production losses and cost increases from changing pest pressures, pest management, and pollination in the VIR.

A Vancouver Island Regional Adaptation Strategies plan was developed by the BC Agriculture & Food Climate Action Initiative, and VIR partners, in 2020 as part of the Regional Adaptation Program launched in 2013-2014 (BC Agriculture & Food Climate Action Initiative, 2020). Plan creation for the VIR involved assessment of climate projections, focus group consultation, and an implementation meeting that prioritized actions. The resultant strategy includes information on the regional context such as the geography, climate, and agricultural production statistics, climate projections, and projected agricultural impacts. Four impact areas were identified as the highest priorities for agricultural adaptation in the VIR, including Impact Area 2: Changing pest and beneficial insect populations. This impact area includes 2 strategies, each with 3 actions and numerous sub-actions. The focus of this project is to develop an implementation plan to prioritize and elaborate on actions and sub-actions within the impact area.

1.1 Objectives and Scope

The purpose of this project is to review and summarize current resources, monitoring activities, and research related to agriculturally relevant pests, pollinators, and pest control species in the VIR, including climate change considerations. In addition, gaps, opportunities, and priorities are identified. Based on this gap and opportunities assessment, an implementation plan will be completed for initiating near- and medium-term project or projects in the VIR.

Two primary areas of information were pursued:

1. Resources available that directly address agricultural pests, pollinators, and/or beneficial species in the VIR, and resources that don't directly address the VIR but are useful for the region. These resources include technical publications, extension materials, research papers, and website/app materials.
2. Research and monitoring that has been conducted within the last 5 years in the VIR on agriculturally relevant pests, pollinators, and/or pest control species.

The information gathering was focused on resources, monitoring, species, and gaps relevant to agricultural crops in the VIR. While resources and some research that are not specific to the VIR are referenced in this report, a comprehensive review of research and monitoring activities from nearby regions, such as the Fraser Valley, are beyond the scope of this project and were recently summarized in other CAI reports such as the Fraser Valley Pest Assessment Report (Scholefield et al, 2017).

The information from the resource, research, and monitoring scan are being used to:

1. Identify gaps, opportunities, and priorities to improve knowledge and management of pests, pollinators, and pest control species in the VIR; and
2. Identify recommendations to expand and/or improve existing monitoring.

2.0 Methods

Three methods of information gathering were employed:

1. Internet searchers for relevant resources, supplemented by contractor knowledge of existing resources.
2. Consultation with key stakeholders to elicit information on resources, knowledge, research, and monitoring of agriculturally relevant pests, pollinators, and pest control species. Stakeholders also were consulted regarding gaps and opportunities.
3. Analysis and consideration of Ministry of Agriculture plant health lab sample history from the VIR.

2.1 Internet searches

Searches on the internet were conducted looking for pest, pest management, and pollinator resources and research in the VIR or nearby. Contractor knowledge of research and resources was used as a starting point for internet searches.

2.2 Consultation methodology

A list of relevant stakeholders was created by the contractors. The objective was to interview 15-20 key stakeholders. The initial list of 27 priority interviewees and 10 secondary interviewees was presented to the Project Oversight Committee (POC) at the first project meeting. Additional interviewees were suggested by the POC, by contractor contacts, and from interviewees. In order to collect data from additional stakeholders than was originally intended, a hybrid approach was employed consisting of phone interviews and an online survey. Survey questions were similar between the phone interviews and online survey and can be found in Appendix 1. Phone interview questions were adapted slightly for each interviewee based on their area of expertise.

In summary, interviewees were questioned on the following topics in relation to the VIR:

- Personal or organizational involvement in relevant research and monitoring
- Key species of concern (current, or anticipated/emerging)
- Identifying gaps (knowledge, resources, monitoring) pertaining to pest pressures
- Identifying gaps (knowledge, resources, monitoring) pertaining to biocontrol insects
- Identifying gaps (knowledge, resources, monitoring) pertaining to native pollinators
- Commonly used resources or supports for pest management and beneficial insect support
- Opinion on the best ways to expand monitoring/research in the VIR or otherwise fill gaps identified in interview

In addition to the phone interview and digital surveys, written input pertaining to specific questions or a subset of questions was received via e-mail and informal meetings with experts. Finally, a small focus group was held with Saanich peninsula and area producers mirroring a subset of the interview questions, in order to get additional input directly from a group of small, medium, and large mixed farms.

2.3 Plant health lab data analysis

To support the project objectives, Ministry of Agriculture entomologists consolidated 5 years (2016-2020) of plant health lab submission data from the VIR. This included a total of 463 diagnoses. Information on the location of origin, crop type, disease/disorder causing factor, and other parameters were discussed, and the Ministry cleaned, filtered, and sorted the data set accordingly for this project's use. Findings from this analysis are shared in Section 5.0.

3.0 Consideration of Climate Change Effects on Agricultural Pests and Beneficial Insects

With climate change, there is increased unpredictability of interactions between weather, cropping systems, beneficial insects, and pests across both time and space. Climate change will affect the distribution of crop pests and the severity of their outbreaks (Lamichhane et al, 2015). It will also affect the populations of their natural enemies/beneficial insects (Thomson et al. 2010). Climate change will impact pollinators in direct and indirect ways (Hegland et al. 2009, Kjohl et al. 2011). In addition, new crops, or combinations of crops, may be grown in new locations and in different growing conditions with changing farming practices. If knowledge and extension are lacking for these new situations, pest issues could become more frequent or more difficult to manage, and pollination may be less reliable. A high-level summary of some of the key impacts of climate change on pests, beneficial biocontrol insects, and pollinators follows.

3.1 Pests

- Increasing invasive alien species and increased pressure from resident populations is predicted with a changing climate (Lamichhane et al, 2015).

- Pest feeding rates increase exponentially with increased temperatures (Kalinkat and Rall, 2015).
- Changes to predator/prey and parasitoid/host populations and functions indirectly due to changes in their habitat structure (Kalinkat and Rall, 2015).
- Crops suffering from water stress are more vulnerable to damage by pests (Heeb et al. 2019).
- Ecosystems that have been disturbed due to extreme climatic events are more susceptible and vulnerable to invasions of alien species (Heeb et al. 2019).

Insect pests

- Climatic projections predict that the distribution of insect species will shift from lower latitudes towards the poles and from lower to higher altitudes (Lamichhane et al, 2015).[1]
- Lower latitudes usually have more pest species and more natural enemies per area than higher latitudes. Therefore, climatic shifts are anticipated to increase the number of pest species in temperate regions, especially in the northern hemisphere (Lamichhane et al, 2015).
- There is the possibility of more generations a year for some pest species, as well as formerly single generation species becoming bi- or multi-generation (Lamichhane et al, 2015).
- Given milder winters under climate change, more species will be able to survive the winter and colonize crops from local populations that have overwintered (Lamichhane et al, 2015).
- In addition, with increasing temperatures, the frequency of spring frosts will decline and extended frost-free periods will increase the length and impact of some insect outbreaks (Lamichhane et al, 2015).
- Earlier plantings, which farmers may implement as an attempt to take advantage of increased growing season length, make crops susceptible to pests earlier in the growing season (Lamichhane et al, 2015).
- CO_2 effects on crop plant chemistry (E.g., carbon-nitrogen balance) and their structure and palatability are different for each species, and is largely unknown (Lamichhane et al, 2015).
- Many insects develop more rapidly in response to rising temperatures, meaning crop damage could occur more rapidly than expected (Kalinkat and Rall, 2015).

Fungi/bacteria

- Elevated CO_2 levels may have negative, neutral, or positive effects on fungal growth (Lamichhane et al, 2015).

[1] mountain pine beetle, a major forest pest in the USA and Canada, has extended its range northward by approximately 300 km when temperature rose by only 2 °C (Logan and Powell 2001).

- Lifecycles of many fungi are moisture-dependent, and outbreaks are often triggered by long periods of wetness (Lamichhane et al, 2015).
- Climate change will influence disease phenology (Lamichhane et al, 2015).
- Climate change may affect the expression of plant resistance traits to fungi in a positive or negative way (Lamichhane et al, 2015).
- There are many documented cases of fungal pathogen adaptation to warmer temperatures, range expansion and aggressive high-temperature-tolerant strains (Lamichhane et al, 2015).
- Similar trends of expansion of range, and increased virulence and aggressiveness are seen in bacterial pathogens (Lamichhane et al, 2015).
- Connected to extreme events, strong air currents in storms can also transport fungal spores or insects from overwintering sites to new areas (Heeb et al. 2019).

Weeds

- It is likely that environmental disturbances such as rising CO_2 and increasing temperatures will be manifested as a change in the competitiveness between crops and weeds (Lamichhane et al, 2015).
- The most likely effect of an increase in temperature is the northwards expansion of native and invasive weed species (Lamichhane et al, 2015).
- Some weeds types are less mobile than other pest types, and their spread and establishment into new regions is likely to take longer than for other pest groups (Lamichhane et al, 2015).
- However, rapid genetic evolution and/or phenotypic plasticity[2] may lead to weed spread faster than anticipated (Lamichhane et al, 2015).

Due to complexities and unpredictability of these combined threats, Lamichhane et al. (2015) advocate for the further integration of the roles of plant health and crop protection experts and specialists for the creation of more resilient cropping systems overall.

3.2 Biocontrol Insects

The literature references diverse, direct, and often indirect effects of climate change on natural enemies. Some of these effects are as follows:

- Abiotic parameters are known to have direct impact on insect population dynamics and direct and indirect impact on biocontrol agents through modulation of developmental rates, survival, fecundity, parasitism, and dispersal are expected and likely with climate change (Palanisamy 2013).

[2] refers to changes in an organism's behavior, morphology and physiology in response to a unique environment.

- Reproduction of natural enemies can alter in response to changes in the fitness of their prey. Quality and health of herbivore pests may benefit from increased plant growth due to temperature shifts as well as increased CO_2 effects (Thomson et al, 2010).
- The susceptibility of herbivore pests to their predators could be decreased through the production of additional plant foliage from increased CO_2 or altered timing of herbivore pest life cycles due to changing plant phenology (Thomson et al, 2010).
- If pest distributions move into regions outside the range of their natural enemies, the effectiveness of natural enemies in controlling pests will decrease (unless a new community of natural enemies also establishes) (Thomson et al, 2010).
- Emerging species often spread into completely new ecological settings where most of their natural enemies are missing, it is unknown whether their predators follow (Lamichhane et al, 2015).
- Mismatches between pests and enemies in space and time likely will be increased by climate change, potentially decreasing effectiveness of biocontrol (Palanisamy 2013).

Ongoing exploration of biocontrol species for new and emerging pests, along with support for diverse communities of wild biocontrol species through habitat integration in agricultural landscapes can help support consistent and resilient biocontrol in the face of a changing climate (Palanisamy 2013).

3.3 Pollinators

Climate change is thought to be a key contributing factor in pollinator declines (Potts et al. 2016). Pollinators, plants, and their interactions will continue to be impacted by a changing climate and some of these effects include:

- Mismatches in plant-pollinator phenology (Memmott et al. 2007, Forrest 2015, Adedoja et al. 2020) with potential impacts on crop pollination (Korosi et al. 2018).
- Greater CO_2 in the atmosphere can reduce protein concentration in pollen, potentially negatively impacting pollinators (Ziska et al. 2016).
- Extreme weather events are contributing to pollinator declines (Soroye et al 2020).
- Loss of native plant resources due to invasions of non-native plants which can be exacerbated by changing climate (see above Section 3.1 Weeds). While some pollinators are generalists and can forage on many plant groups, many native pollinators are more specialized and rely on native plant species (Ramos-Jiliberto et al. 2020).
- Increased and changing pest pressure for both native and managed bees. Changing climate could increase virulence of diseases and bring new species into contact (Reddy et al. 2012).
- Earlier planting of crops due to warmer spring temperatures may not time with crop-pollinator emergence (Kudo and Ida 2013).
- Pollinator behavioural responses to avoid extreme temperatures have the potential to significantly reduce pollination services (Kjøhl et al. 2011).
- While thermal tolerances are missing for most bee species, it is expected that there will be range shifts and contractions due to increasing temperatures (Kjøhl et al. 2011).

- Similarly, range shifts and contractions are expected for native plant species due to altered moisture levels and rising temperatures, impacting pollinator communities (Simon 2020).
- Drought, water stress, and increasing temperatures are expected to impact floral characteristics in wild and crop plants, possibly reducing the number and/or quality of flowers, and nectar and pollen. This reduction in floral abundance and/or rewards could reduce attractiveness of wild plants and crops, in turn reducing the number of pollinator visitors, and seed and fruit production (Kjøhl et al. 2011).

Ecosystems that support a diverse community of pollinators have been found to provide more consistent and robust services, which is attributed to species functional complementarity and biological diversity insurance (Garibaldi et al. 2011, Korosi et al. 2018, Woodcock et al. 2019). With future changing climate it is important to preserve diverse populations of pollinators which will help insure pollination in changing conditions (Brittain et al. 2013). Being dependent on few pollinators for crop pollination (such as the interviewee-reported reliance on managed honey bees for some crops in the VIR) makes agricultural systems particularly vulnerable to climate change and the impacts that climate change will have on any one species such as honey bees (Kjøhl et al. 2011)

4.0 Results of Scan and Gaps in the VIR

4.1 Consultation

In total, 18 stakeholders were interviewed by phone and eight stakeholders completed the online survey. Two additional individuals provided written comments by e-mail, and five producers participated in an informal Saanich Peninsula and area producer focus group. In total, input was received from 33 stakeholders. Interviewees included: producers, provincial government, federal government, non-profit/non-governmental organizations, private consultants, and academic researchers. Production types or areas of focus included: entomologists, pollinator specialists, invasive species specialists, berry crops, forage crops, tree fruit crops, beekeepers, vegetable crops, organics, and mixed farms. A full list of stakeholders that were interviewed or participated in the survey are listed, with their affiliation and crop type, or body of knowledge that they represent, in Appendix 2.

The degree of participation varied between industry associations, resulting in inclusion of more in-depth information for some commodities versus others. For example, the berry industry (blueberry, raspberry, and strawberry industry groups) has a staff person responsible for research, who was able to provide a list of priority pests and a list of current research for all three groups. In comparison, equivalent information was not provided from any of the other industry association groups that were contacted at the project inception. In addition, every attempt was made to identify and describe current monitoring activities, however, it is possible

that not all are captured in this document, especially small scale and independent monitoring activities.

4.2 Resources and Research Scan Summary and Gaps

Appendix 3 lists resources including guides, websites, reports, and relevant research on agriculturally relevant pests, pollinators, and pest control species that are useful for the VIR. While many avenues of inquiry were pursued and many stakeholders contacted, it is possible that some relevant resources are not included in this summary.

All of the resources listed pertain, at least in part, to species that are found (or are believed to be present) on Vancouver Island; this was the primary criteria for inclusion. However, out of these, far fewer (59%) were created for BC and/or the Pacific Northwest. Fewer still (12%) were created specifically for Vancouver Island, and an estimated 18% are believed to incorporate or present some information from Vancouver Island within the resource or tool.

Research and Resources Underway

The research and resources underway, as documented in the table, are all BC-based research with relevance to the VIR. Due to the study limitations, as well as the size of the berry sector in the Lower Mainland, berry-related pest management research represents a large portion of the research listed. Stakeholder-identified species of concern are represented within this list, such as: wireworms, army worms, pathogens, issues caused by nematodes, and spotted wing drosophila. Research is being conducted by the federal government, industry associations, and BC universities, as well as partnerships between these groups.

Reports and Fact Sheets

In the list of completed reports (technical and research reports) and fact sheets, climate change and pest focused work completed by the BC-CAI in other regions is included. Of these resources, the Fraser Valley – Agricultural Pest (Activities, Gaps & Priorities) Assessment is the most relevant resource for the VIR. This inventory and assessment includes a list of 328 pest-related projects in the Fraser Valley as of its 2016 publication date, and includes an inventory of the pests of concern and monitoring efforts organized by crop type for 30 crop types. A careful review of this inventory was beyond the scope of this project, but this action is included for consideration in Section 7.0.

This section also includes nine resources pertaining to pollinators (ecology, habitat, pollinator/crop interactions, pollinator health) which are all relevant to the VIR, and most of which were either produced for Vancouver Island or include VIR findings.

Production Guides and Other Guides

The BC Production Guides were considered by interviewees to be the best all-round source of information on pest management for BC producers. These guides exist for most crops in the VIR and are easy to access online. The table also includes field guides for insect ID, pollinator plantings, and biodiversity and beneficial species support. The source identified on beneficial insects is not from BC, or Canada, and availability of this information may be a gap.

Websites and Mobile Apps

This section includes a small selection of organizational websites, included for their expertise in the project area and their local focus. The apps that are widely used by these organizations, and professionals in the field are included. It is common for these more well-funded and professional apps to include systems for quality control and an interface with expert support. Apps were reported by stakeholders as being very effective for monitoring, pest identification, and, in some cases, management.

Resources from Other Jurisdictions

It is common for producers, and government, to turn to resources from other jurisdictions where local information gaps exist. For certain commodities, the research from south of the border is quite transferable. For other commodity groups, resources are utilized from eastern Canada or eastern US, which probably require more interpretation for transfer to the VIR climate. While it is not exhaustive, this section of the resource/research review lists a few of the primary sources of information from other jurisdictions that were referenced by stakeholders. Stakeholders also mentioned that European resources are commonly accessed, but no specific resources were mentioned. Of the resources summarized, the UC Statewide Integrated Pest Management Program (IPM), the Canada Horticulture Council Crop Profile Sheets, and the Washington State University Agriculture Extension Pests, Plant Diseases and Weeds Page collectively contain a tome of information, and specialists from each crop type would be equipped to review the transferability of specific resources therein.

Research and Resource Gaps

While only 12% of resources listed were created specifically for Vancouver Island, and an estimated 18% are believed to incorporate or present some information from Vancouver Island, this is not considered to be a gap for most commodity groups, since so many resources were identified from similar climates (especially the Fraser Valley).

Key gaps from the research/resource scan are[3]:

[3] Follow up with additional experts is needed to confirm these gaps, and/or to identify if there are any existing resources with transferability to VIR.

- Pest management:
    - Research pertaining to biological controls
    - Research including VIR trials
    - Treatments for new and emerging pests
    - Treatment options for the organic sector
    - Resources to support identification of beneficial insects
    - Extension resources on biological controls for VIR (or BC) producers
- VIR forage sector:
    - Recent VIR or Pacific Northwest focused production guide for forage
    - VIR or Pacific Northwest focused IPM guide for forage
- Pollinators:
    - Research on pollinator communities, crop pollination by managed and wild pollinators, and landscape/agricultural population associations in the VIR

4.3 Monitoring Summary and Gaps

Monitoring activities in the VIR are listed and briefly described in Appendix 4.

Pests

Monitoring for pests in the VIR is mainly conducted by the CFIA (primarily invasive arthropod species), the BC Ministry of Agriculture (generally responsive to outbreaks with a focus on arthropod pest species of concern), and the Coastal Invasive Species Committee (focus on invasive plant species). The CFIA and BC Ministry of Agriculture monitoring programs range in duration from one season to many seasons for some species, they are specific to pest species that are of concern, and the data generally are not publicly available. They provide information that is important for responding to pest incursions and outbreaks, understanding species distributions, and changes in distributions and abundances of pests.

Other monitoring for pests is conducted by IPM consultants, however, there are few IPM consultants in the VIR, relatively few farms contract their services, their data is not necessarily standardized or conducted on a landscape scale, and the information is not publicly available. Growers who are contracting IPM consultants are typically larger growers who need to do so to meet export requirements or other certification requirements. This includes berry exports to Asia and organic growers which are required to submit lists of the pests on their farms for organic certification. Growers often conduct their own pest scouting within their crops, but this is not done in a comprehensive, systematic way, and is generally completed ad-hoc along with other field activities. Therefore, there is little standardization or information sharing from grower monitoring. Community monitoring such as the Metchosin Biodiversity Project, while not specifically designed to monitor agricultural pests, have collections from standardized methodology and data (to coarse taxonomic group) that is publicly available.

Monitoring for the Asian Giant Hornet (AGH), an invasive wasp that is a honey bee predator (and possibly can impact wild pollinator populations), is being conducted in the VIR due to its potential impact on managed honey bees. An individual associated with the Nanaimo

Beekeepers Association had put out traps and distributed about 60 traps to members of beekeeping associations on Vancouver Island in 2020 (in consultation and collaboration with the BC Provincial Apiculturist). None were found on Vancouver Island in 2020. In 2021, there is a similar plan to distribute traps among beekeeping groups in order to monitor in the Nanaimo and Duncan area. In addition, online reporting and identification is available through the BC Provincial Apiculturists for possible public sightings of AGH.

Most respondents indicated that CFIA and BC Ministry of Agriculture monitoring adequately addresses pests of concern in the VIR. Continuation of these responsive monitoring activities (to existing and potential pests of concern) is important and should remain consistent into the future by the current groups if possible, or by other groups if these groups discontinue or scale-back efforts. However, it was indicated that there is a large gap in the VIR in *general* (less targeted) pest monitoring which could help detect new pests before they become a problem, give an early warning, and improve understanding of current populations of pests that may increase or become more problematic with climate change.

Beneficial arthropods

There is no standardized, and/or coordinated, and/or long-term monitoring of agriculturally important beneficial arthropods in the VIR.

Biocontrol species

This project review found no monitoring programs for biocontrol organisms in the VIR. IPM consultants take note of biocontrol species (or evidence of species) while scouting crops and some growers may also incidentally note biocontrol species in their crops, but this is relatively uncommon. General arthropod monitoring such as the Metchosin Biodiversity Project would have some information, but community biodiversity programs do not target agriculturally important species and often identification is not sufficient for understanding population and species distributions, and habitat associations. The Royal BC Museum has a current focus on spider collections (which can be beneficial in agriculture), but these collections are mainly for the purpose of species identification and range information, unrelated to agriculture.

Pollinators

There have been some collections of pollinators for non-agricultural research programs and projects, for example Simon Fraser University research on plant-pollinator interactions in Garry oak ecosystems has been conducted in some years on Vancouver Island, University of Victoria research on bumble bees on Galiano Island, and BC Ministry of Environment collections of at-risk species. For the most part, these data are available, but they are limited in terms of applicability to agriculture, and do not directly address the gaps in monitoring and research of pollinators in relation to VIR agriculture. However, plant-pollinator data generated by some of this research can help inform habitat optimization for pollinator support.

4.4 Gap Summary Tables from Stakeholder Interviews

The tables of gaps presented are based on stakeholder interviews. Options were presented to stakeholders under each of the three themes (pests, biocontrol, pollinators) and they were asked to score which prompts they agreed with were significant gaps (such as in knowledge, action, or resources; see Appendix 1). Stakeholders were also encouraged to expand on the options presented and discuss additional gaps. Tables are loosely ordered with topics that were identified by more interviewees at the top of tables. Some topics are broader and may have been discussed by more people because of their broad nature while other topics are more specialized. Therefore, the order of gaps does not necessarily reflect an importance level. Discussion of the gaps, including more detailed information of what was discussed by interviewees is outlined in Section 4.5.

Table 1: Gaps in pest knowledge, action, and resources specific to the Vancouver Island region

Gap
Grower knowledge (management, options, importance of pest control and prevention, cultural control and IPM options, thresholds, using biocontrol, pest identification, resources)
Extension to growers (awareness of resources, lack of consultants, biocontrol options)
Knowledge of main pests (biology, range, lifecycle, management options, host plants, threshold treatment levels)
Biocontrol feasibility (knowledge/research gap)
Threshold treatment levels (knowledge/research gap)
Lower environmental impact non-chemical control options (grower knowledge and research)
Pesticides (efficacy, selection: research gap and grower knowledge gap)
Restricted treatment options (E.g., herbicides for weeds, organic production)
General monitoring- ongoing, not target, standardized

Points/modes of entry for many pests
Pesticide impacts (including those thought to be harmless) (E.g., Btk)
Virus diagnostic capacity
Decision aid tools for management, particularly diseases
Treatment options for organic growers
Fungicide options

Table 2: Gaps in biocontrol knowledge, action, and resources specific to the Vancouver Island region

Gap
Knowledge of predator/parasitoid communities
Effectiveness studies (especially local studies, and economics)
Habitat support
Knowledge of biocontrol options and procedures
Benefits of habitat for pest control (many VIR growers understand planting habitat for honey bees but not the pest control benefits)
Understanding how biocontrol works (E.g., time it takes to be effective, early intervention etc.)
IPM practitioners in the VIR
IPM resources specific to the VIR
Financial support

Technical support
Supply of biocontrol agents
Outreach/extension/information from non-biased sources

Table 3: Gaps in pollinators knowledge, action, and resources specific to the Vancouver Island region

Gap
Habitat support
Main pollinators of agricultural in the VIR
Optimizing planting value to pollinators
Crop reliance on pollinators
Efficiency of different pollinators (best pollinators/how to target support)
Pesticide impacts to pollinator health
Impacts of non-native pollinators (positive or negative)
Native bee awareness
Economic evaluation of habitat from local research/data
Financial support for habitat creation
Producers knowledge of pollinator habitat
Reliance on honey bees

Native bee management (mason bee management) education

4.5 Commentary on Gap Summary Tables

Pests

Most interviewees identified aspects of knowledge of pests as a major gap in the VIR. While there was some discussion of lack of knowledge of ranges, biology, and lifecycles of pests, this information was generally thought to be available and applicable from other regions, and the largest gap identified was in grower knowledge of pests including the importance of management and prevention, options for management including lower impact chemical options, cultural control, treatment thresholds, other IPM options including biocontrol, and resources available to growers. There is a lack of awareness, especially among smaller growers, of both public resources (Ministry staff, diagnostic lab) and private resources (supplier extension, professional consultants).

"There is no lack of resources. Only grower specific gaps." -Stakeholder Interview

Respondents felt that there is a lot of interest in biocontrol, both conservation biocontrol (CBC) and biocontrol organism release, but there is a lack of extension and resources for growers which hinders understanding and more widespread adoption. One interviewee expressed that treatment threshold levels are pretty well understood by growers for pests that have been in the region for some time, but that growers were not familiar with how and when to treat pests that are new to the region. A few interviewees said that smaller growers do not know how to deal with weeds. Three of the interviewees discussed increasing regulations, lack of options, and lack of access to effective herbicides to control problematic weeds as an issue in the VIR.

Some smaller and organic growers are unable to identify many pests, largely due to the breadth of pests that affect their operations. Small scale growers were identified as generally having more awareness and understanding of biocontrol options and IPM than larger scale growers. However, one interviewee expressed concern that some small-scale growers were reluctant to treat pests with chemicals and having no other immediate treatment options this has contributed to large scale pest outbreaks on their operations due to lack of early control.

Another gap is IPM resources for certain crops and for the scale/size of farm that is common in the VIR. Future work should verify whether the IPM resources identified in the Fraser Valley or from US can be transferred to a VIR context. There is a gap in forage specific IPM and pest management support. This crop is often un-irrigated, making it more susceptible to pest pressures associated with extended dry periods. Many forage producers in the VIR (mid-island) were subject to major forage crop losses (and one interviewee lost the ability to continue

producing on a section of leased land) with the 2017 army worm outbreak, so additional resources are needed for the forage sector to prevent and control pests.

With respect to identifying and understanding disease/disorders caused by non-arthropod pests, there was a gap identified for pathology/virus identification and proper treatment. Consultants can guess what a virus is based on the history of the site or production guides, but the only way to confirm is in the lab and there are limited diagnostic tests and capacity for testing viruses.

Gaps in knowledge (research) were not identified by many interviewees as a large concern as information is available from other regions that is applicable to the VIR. However, to fill some gaps, local research supported by the government was identified as lacking in the VIR. This research should be government and/or commodity group supported, should include grower involvement via on-farm experimentation or demonstration, and results should be available to all growers. One knowledge area that was identified as a gap was host plants for pests. Lack of knowledge of non-crop host plants limits ability to control pests through vegetation management and some growers are reluctant to create habitat for beneficial insects because of the concern that they may enhance pest insects. Pollinator Partnership Canada is creating a searchable database of non-crop host plants for some economically important pests in Canada (to be released in 2021). Further research on net impacts of non-crop host plants in the VIR is necessary to understand the complex relationship between beneficial insect support, pest pressure, predation and parasitism, and the economic cost-benefits of habitat.

Many interviewees identified a lack of standardized, broad monitoring as a large gap in the VIR. It was discussed that the CFIA and other groups do targeted surveillance for invasive species but that there is no ongoing, arthropod pest monitoring that is centrally coordinated. This type of standardized monitoring would be valuable for understanding pest abundances and distributions, changes in abundances and distributions, landscape factors associated with abundances and distributions, and for early detection of novel pests. Data from wide-scale monitoring should be centrally managed and publicly available. There are few funds however for processing and identification of specimens which would need to be addressed if large-scale monitoring were to be initiated.

The gap in grower knowledge that was identified is closely tied to the lack of extension identified by most of the interviewees. It was expressed by many that extension to growers was lacking in many aspects including not enough extension personnel and crop consultants, and lack of outreach to growers about existing resources. The lack of pest control crop consultants may partially be due to inability/unwillingness of farmers to pay for this service. That many growers use pesticide company representatives for pest management advice was brought up by a few of the interviewees as less than ideal due to conflicts of interest and probable promotion of pesticides over IPM methods. Conversely, others expressed that VIR supply companies are well-versed in organic and IPM pest control methods and provide balanced information. There are two regional agrologists on Vancouver Island and they are not specialists in specific crops but are rather generalists whose mandate is to support the agriculture sector at a high-level through broad sector initiatives. Ministry of Agriculture Industry Specialists are scattered

throughout the province and have very little interaction with VIR producers. One interviewee suggested that there is a need for Provincial extension offices that specialize in the various growing regions.

Biocontrol

There was strong consensus among interviewees that the three gaps presented (interview prompts/suggestions); knowledge of predator and parasitoid communities, local studies on effectiveness and economics of biocontrol, and support for habitat creation were all significant gaps in the VIR. It was emphasized by a number of interviewees that local knowledge of beneficial insect communities in the VIR was lacking and that local research is necessary to address this gap. While biocontrol studies are available from other regions (E.g., Collins et al. 2003, Holland et al. 2017, Morandin et al. 2016) the unique ecosystems in the VIR require local studies to assess interactions between biocontrol species and pests in relation to local landscape characteristics and cropping systems. Local studies would help generate information on optimizing habitat for beneficial insect support, economically important species, efficacy for control of various pests, and the effectiveness of release options. Local studies and data are necessary for grower confidence in this approach and for wider adoption of biocontrol practices in the VIR.

Additionally, support for habitat creation/preservation for biocontrol species was identified as a significant gap. Grower adoption of habitat integration practices can be optimized with a combination of financial support for habitat restoration, technical advisors, and demonstration habitat (Garbach and Long 2017). It was noted that in the VIR there are very few government extension staff that could help advise on biocontrol and habitat support. There are some private IPM consultants in the VIR, but relatively few compared to other, more agriculturally intensive regions of BC such as the Fraser Valley. Cost of IPM consultants also limits grower uptake of their services and many growers' primary source of information on pest control are pesticide representatives.

Additional gaps in the VIR included grower lack knowledge of biocontrol options and procedures. For example, which biocontrol organisms to use and what is available for purchase (many know of lady beetles but have little knowledge of biocontrol organisms beyond that), how and when to release biocontrol species, how biocontrol organisms work and what to expect (E.g., pest control results will not be immediate, early release and prevention is key etc.). There is a general lack of understanding that pest control can be relatively simple, according to one interviewee, if pests are maintained under economic injury thresholds, but outreach and professionals are needed to help growers better understand this. It was also mentioned that supply of biocontrol organisms was not always sufficient in the VIR and that biocontrol organisms (release) are not an option when dealing with new pest invaders. Creating robust ecosystems that support biocontrol organisms (Conservation Biocontrol; CBC) could help reduce the impact of newly introduced pests, especially if generalist predators are supported by habitat.

One interviewee expressed that many growers do not understand the importance of habitat for supporting and enhancing biocontrol organisms. Instead, growers were more familiar with habitat as a means to support bees (primarily honey bees, there is less awareness of native bees). Greater outreach in the VIR to translate the large body of literature on CBC which shows effective control of some pests, in addition to local research and extension, is necessary for greater adoption of habitat integration in agricultural lands.

Pollinators

Most of the people interviewed agreed that there are major gaps in the VIR in relation to habitat support for pollinators, understanding of the main agricultural pollinators in the VIR (due to lack of monitoring/surveys and research), and gaps in local research and understanding on optimizing plantings for pollinators. Many people also identified lack of knowledge of crop reliance on pollinators (importance of pollinators to the crop), efficacy of different pollinator groups, impacts of pesticides, and impacts of non-native pollinators on wild pollinators as significant gaps. There is summary information available on reliance and attraction of all crops in Canada to bees available upon request from Pollinator Partnership Canada from work commissioned by the PMRA. However, there are many knowledge gaps in crop reliance and local information on which pollinators are visiting which crops and information on relative importance are missing for many crops and for many regions.

A very striking gap in the VIR is the lack of any coordinated or consistent monitoring of agricultural pollinators. There have been some wild pollinator research studies and collections in relation to Garry oak ecosystems in the VIR, one MSc thesis project on bumble bees on Galiano Island related to climate change, and some monitoring of threatened pollinator species. However, the complete lack of agricultural pollinator monitoring and research in the VIR should be addressed.

In terms of monitoring pollinators, there are many options for filling the gap in the VIR, including hybrid expert-citizen scientist models. However, all future monitoring plans need to address specimen processing and identification bottlenecks, and identification ability with non-destructive sampling (only to coarse taxonomic levels without specimens). In the US, a National Native Bee Monitoring Network is being established and that model could be assessed for components that would be valuable for establishing a centralized pollinator monitoring program in the VIR (Woodard et al. 2020). The BC-CAI is working with UNBC and other project partners to pilot a baseline pollinator assessment in the Bulkley-Nechako and Fraser-Fort George (BNFFG) region as a part of implementation of the BNFFG Regional Adaptation Strategy, outcomes of this pilot could inform a future VIR similar pilot project.

In addition, there is no research to our knowledge on habitat benefits and support optimization for pollinators and crop pollination by wild bees specific to the VIR. The lack of local research and local demonstration (sites and data) limits the ability and willingness of growers to create habitat for pollinators. Especially important are cost-benefit studies of habitat creation for the VIR; ecosystem service cost-benefit analyses for CBC and pollination are rare but are available

for some other regions (E.g., Morandin and Winston 2006, Blaauw and Isaacs 2014, Morandin et al. 2016).

As general awareness of the importance of wild pollinators for crop pollination increases (Garibaldi et al. 2013, Rader et al. 2013, Garibaldi et al. 2014), it is important that this monitoring and research gap is addressed in the VIR. Healthy and resilient wild pollinator communities are essential to the long-term stability of pollinator-dependent crop production. Complementarity among bee functional groups results in more stable and consistent crop pollination, especially in the face of a changing and unpredictable climate (Garibaldi et al. 2011, Rader et al. 2013, Woodcock et al. 2019). Problematic honey bee health and colony supply, which may be exacerbated by climate change (Reddy et al. 2012), makes it even more imperative to understand best management practices for supporting and enhancing wild pollinator populations so that there is less reliance on a single, managed pollinator species (Brittain et al. 2013). It was expressed by one interviewee that reliance on honey bees for pollination in the VIR is wide-spread and not ideal. In addition to honey bee health and supply being uncertain, honey bees are not the best pollinators of many of the crops (Garibaldi et al. 2013).

Local research is necessary, but greater extension also is needed. One interviewee said that they see little awareness in the VIR of the importance of wild bees for crop pollination and of habitat for wild bee support (growers mainly understand the benefits of habitat creation for honey bee support). Greater outreach to growers on reliance of crops on pollinators, benefits of managed and wild pollinators to production, how habitat can increase populations of wild bees and crop productions, cost-benefits of habitat creation, and technical guidance on habitat creation and optimization will help increase adoption of habitat integration practices. While there is not a lot of large-acreage farms with pollinator-dependent crops in the VIR, many of the crops in smaller, mixed farms are pollinator-dependent. In addition, it was identified that growers would benefit from more information regarding native bee management for agricultural pollination (and studies on effectiveness such as mason bee management).

Another major gap identified for the VIR is financial support for habitat creation for beneficial insects (CBC species and pollinators) which is necessary for widespread adoption. There are many agri-environmental cost shares program models from the EU (greening measures/green payments) and the US (E.g., EQIP cost share grants) and some smaller-scale, non-governmental programs from other regions of BC (E.g., Farmland Advantage) and Canada (E.g., ALUS) that could be used within the VIR. Within BC, the BC Environmental Farm Plan program will be including more BMPs and support for biodiversity pollinator practices going forward.

4.6 Priority Pests

Pests of concern are listed in Appendix 5 and represent pests that were discussed or listed by interviewees. While a robust ranking of current and potential future pests of concern in the VIR is beyond the scope of this contract, some pest species were discussed by multiple

interviewees, and/or were highlighted as key pests of concern by Ministry of Agriculture experts, and/or are species groups containing numerous species of concern in the VIR. The top pests of concern were (in alphabetical order):

1. Asian giant hornet
2. Brown marmorated stink bug
3. Cutworm (*Agrotis* spp)
4. Grape phylloxera (and other root aphids)
5. Leafrollers (*Tortricidae* spp)
6. Powdery mildew
7. Spotted wing drosophila
8. True armyworm
9. Viruses (general)
10. Western corn rootworm
11. Wireworm

Another method for prioritizing pests from the longer list is to consider which pests affect the most prominent crop types in the VIR. The most prominent production types in the VIR as measured by productive acreage is forage production (BC Agriculture & Food Climate Action Initiative 2020), and by number of farms are: fruit and tree nut farming; and greenhouse, nursery and floriculture production (consisting mostly of nursery and tree) (Statistics Canada, 2016). The prominent pests from the Appendix 5 list affecting these production types are (in alphabetical order):

Forage

1. Leather jacket
2. True armyworm
3. Western corn rootworm
4. Western yellowstriped armyworm

Berries

1. Blueberry maggot
2. Brown marmorated stink bug
3. Cranberry tipworm
4. False blossom
5. Grapevine leafroll associated virus
6. Japanese beetle
7. Leafrollers (*Tortricidae* spp.)
8. Lygus bug
9. Nematodes
10. Ripe rot
11. Rose stem girdler
12. Spanworm (*Geometridae* spp.)
13. Spotted lantern fly

14. Spotted wing drosophila
15. Strawberry blossom weevil (and other *Cuculionoidea* spp)
16. Verticillium wilt

Tree Fruit

1. Ambrosia beetles
2. Anthracnose canker
3. Apple decline
4. Apple maggot
5. Apple scab
6. Coddling moth
7. Eastern filbert blight
8. Spotted wing drosophila

A robust review and ranking of current and emerging priority pests in the VIR could be conducted following the methods used for creation of the Priority Pests for the Cariboo-Chilcotin Final Report (Powell 2018), wherein an in-depth ranking system was created and involved targeted consultations and literature review for each candidate pest. The ranking included information on geographic scope, potential geographic scope if unmanaged and in the context of climate projections, scale of impacts, severity of impacts on crop quantity, quality and/or yield, and existing monitoring and management support (i.e. effective Best Management Practices).

While there were many pests that stakeholders were concerned about, most respondents indicated that CFIA and BC Ministry of Agriculture monitoring addresses those major pests of concern in an adequate manner. Continuation of these responsive monitoring activities (to existing and potential pests of concern) is important and should remain consistent into the future by the current groups if possible, or by other groups if these groups discontinue or scale-back efforts. However, it was indicated that there is a large gap in the VIR in *general* (less targeted) pest monitoring which could help detect new pests before they become a problem, give an early warning, and help better understand current populations of pests that may increase or become more problematic with climate change.

5.0 Plant Health Laboratory Sample Summary

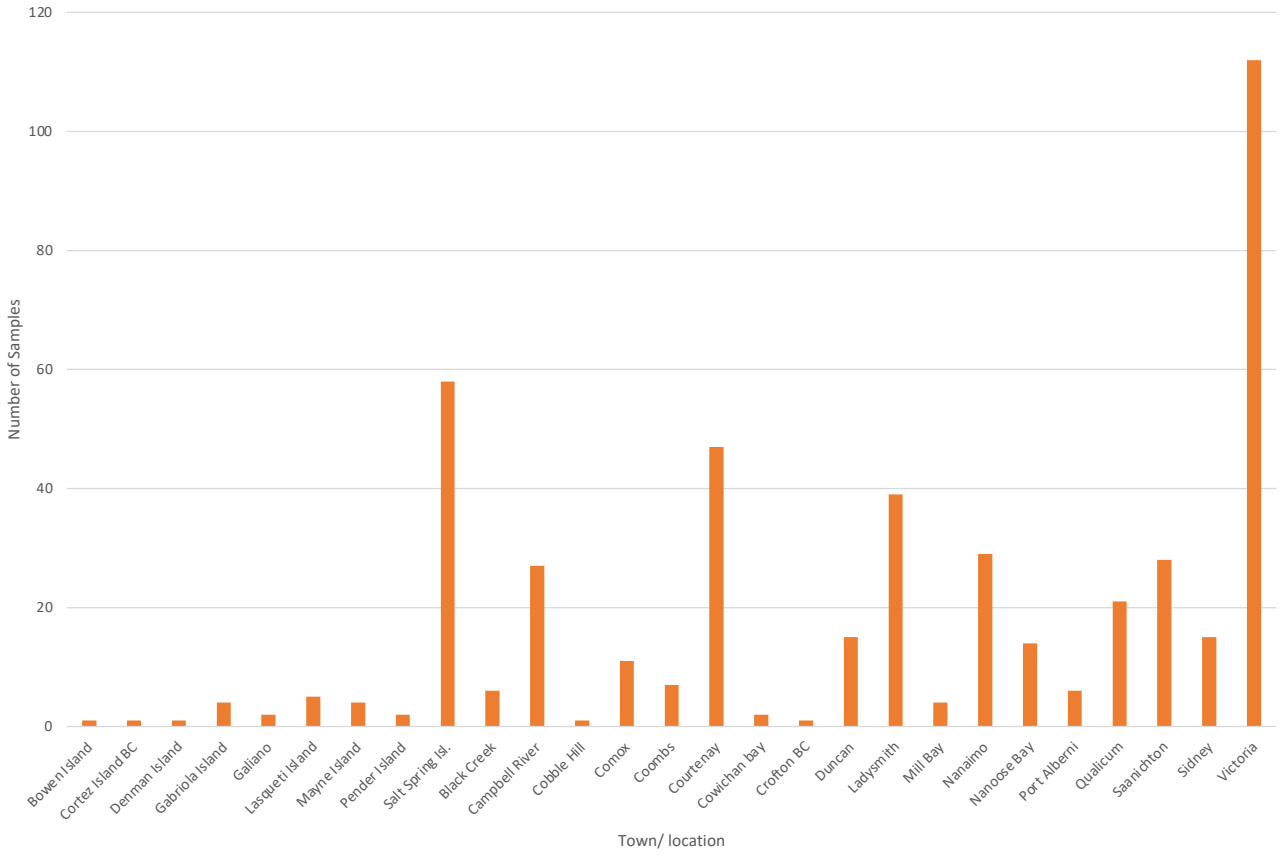
The Plant Health Laboratory provides diagnosis of plant health problems caused by insects and diseases affecting crops and plants grown in B.C. including plant diseases, non-pathogenic disorders, and insect pests. Samples for diagnosis are shipped directly from growers, or other specialists, to the Ministry and processed for a small charge depending on urgency (7 weekdays = $31.50, 7-10 weekdays= $21.00, 10-20 weekdays= $15.75).

Producers from across the VIR are making use of this lab for diagnosis of crop diseases and disorders. Use of this resource is presented below by geography, crop type, submitter, and

causal factor in order to understand which locations or groups could be made aware of the lab or encouraged to access this resource.

Geographically, Victoria had the highest submissions on Vancouver Island. Locations were grouped into VIR sub-regions for analysis (south = Nanaimo south, mid = north of Nanaimo to Campbell River, north = north of Campbell river). Salt Spring Island had the highest submissions from all of the Gulf Islands. There were no submissions from the north sub-region. Figure 1 shows submission by town.

Figure 1: Plant Health Lab Submission by VIR town

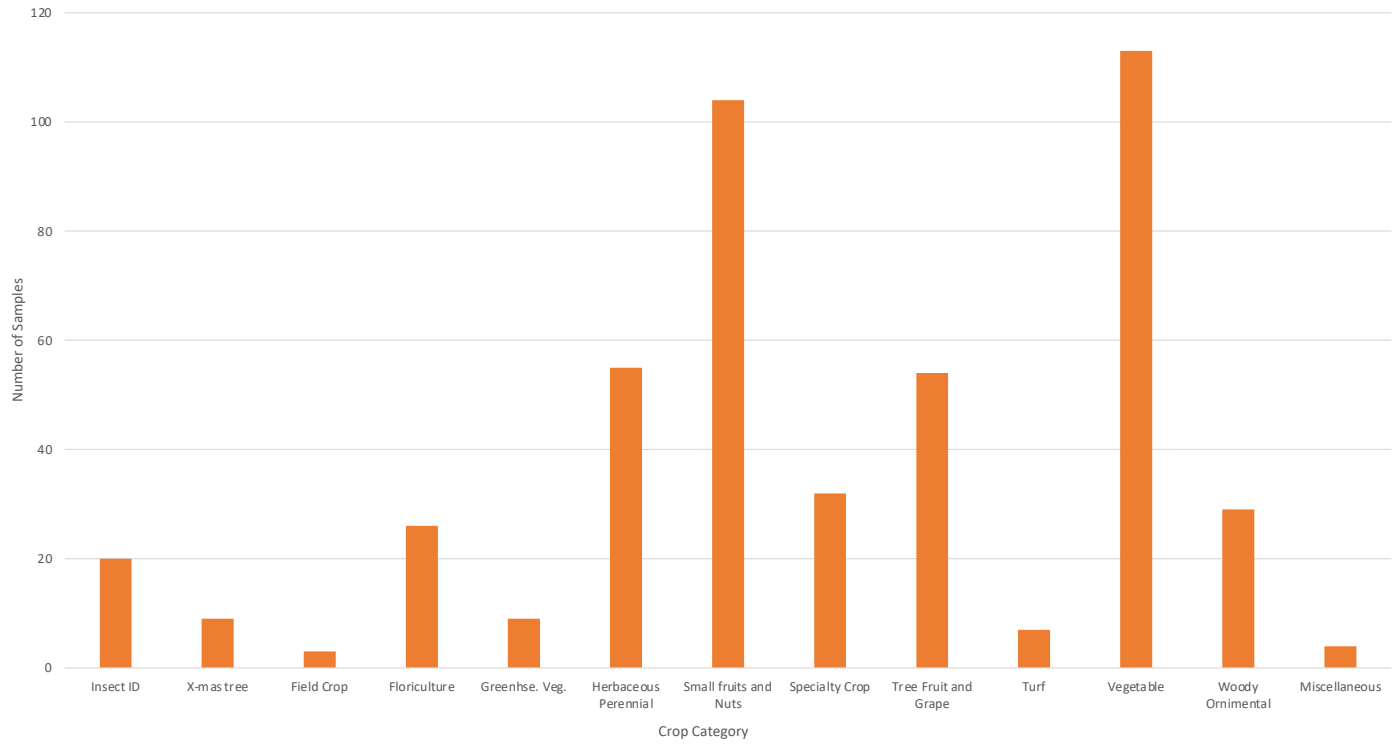


Samples were submitted for 87 crop types in total. The most frequently submitted crop sample types were garlic, *Buxus* (boxwood ornamental), raspberry (followed closely by blueberry and strawberry), and specialty samples including cannabis and wasabi. Once grouped into categories, this made the “vegetable” group the largest crop category, followed by “small fruit and nuts”, then “herbaceous perennial” Some of the reasons for the prominence of these crop samples are:

Garlic: Growers appear to be using the lab for screening for phytosanitary and marketing reasons, and looking at overall plant health rather than to diagnose a particular issues or condition
Buxus: Probably looking at boxwood blight (*Volutella buxi*), which is a new disease of boxwood.
Cannabis: from samples grown in Nanaimo, likely from a single or small number of commercial growers.
Wasabi: from samples all grown in Nanoose Bay, likely from a single grower.

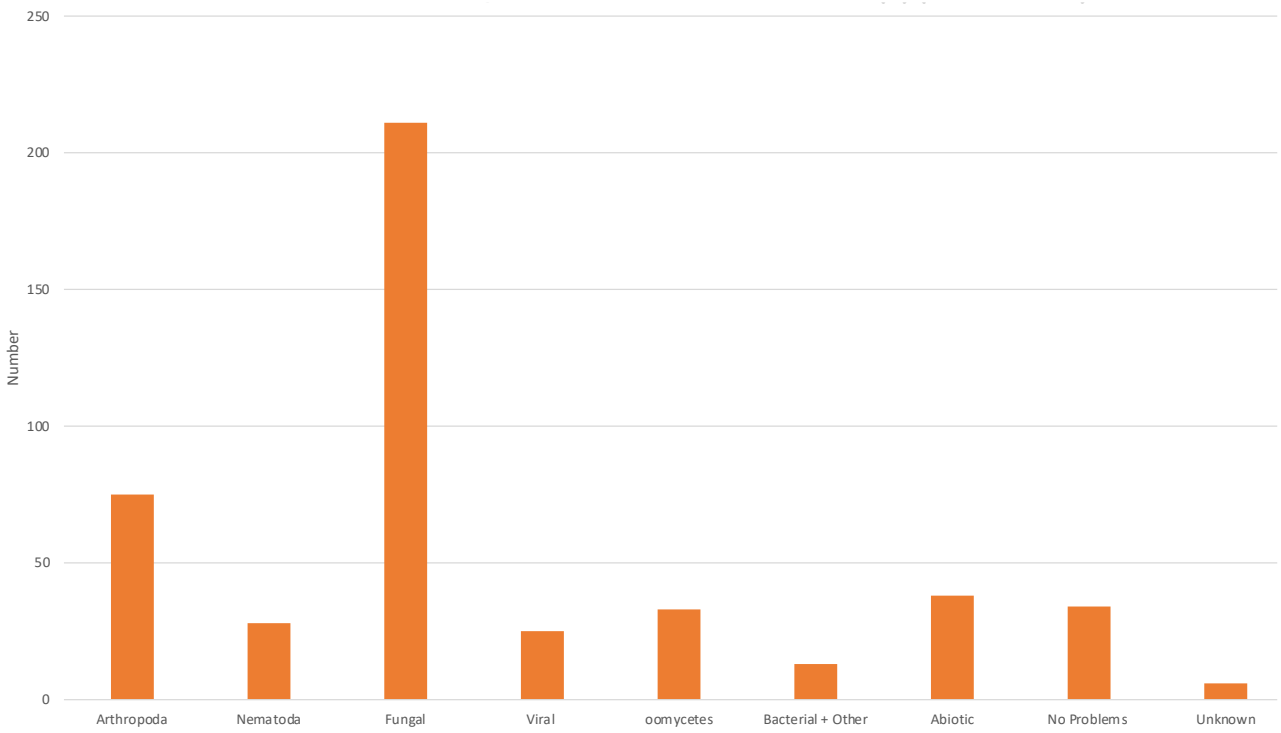
There were also a substantial number of samples submitted from apple and potato. Figure 2 shows submissions of crop-by-crop category.

Figure 2: Plant Health Lab Submission by Crop Category



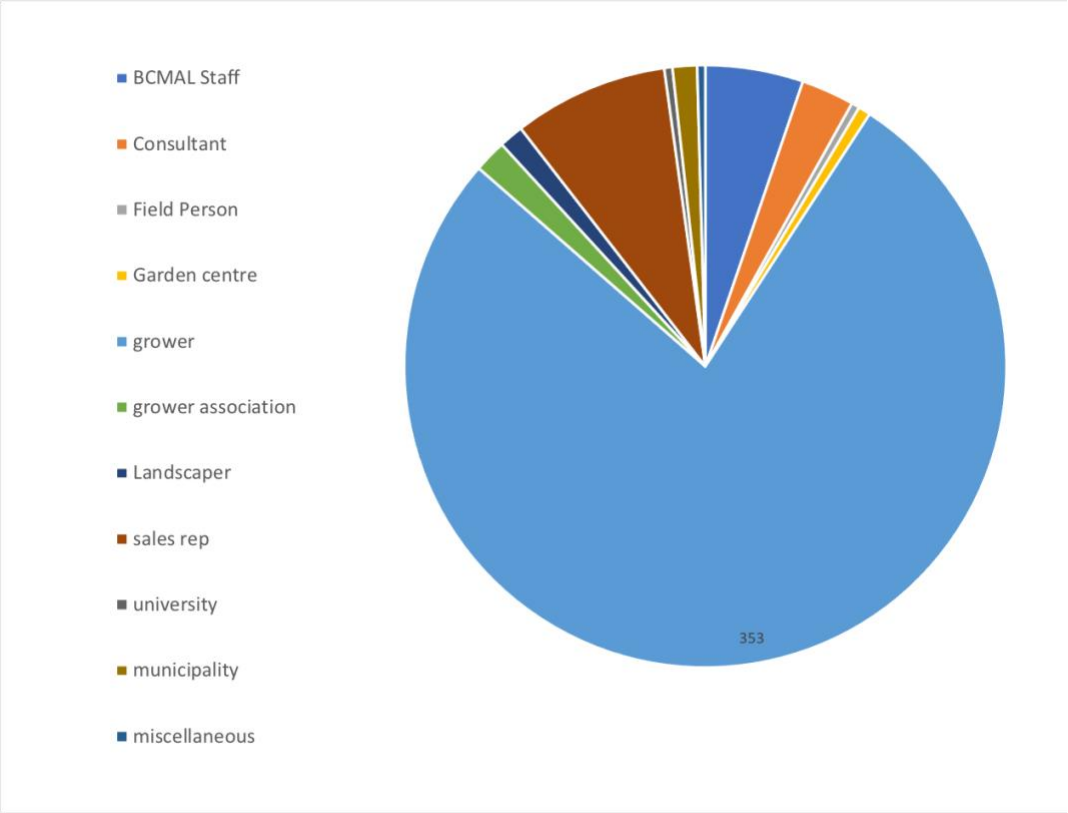
The lab results showed that fungal pathogens were by far the highest causal factor for diseases/disorders, consisting of 211 samples. There are approximately 69 different species present among these samples (42 of these appearing only once in the samples). The breakdown of the other causal factors are arthropods (75), abiotic factors (38), oomycete/water molds (33), nematodes (28), viral (25), bacterial (13). Figure 3 shows the breakdown by disease/disorder causing factors.

Figure 3: Plant Health Lab Submission by causal factor



To understand where submissions to the lab are coming from, and whether individual growers are aware of this service, or whether the samples are solicited and sent in through another avenue, the Ministry of Agriculture also provided a breakdown of submitter type. Figure 4 shows that the vast majority of samples are submitted by growers (77%), followed by sales reps (8%), BCMAL staff (5%), and consultants (3%). Other submitter types include field person, garden centre, grower association, landscaper, municipality, university, and other.

Figure 4: Plant Health Lab Submission type



6.0 Opportunities

Opportunities abound to build on the existing foundation of partners, resources, and experts in the VIR and nearby. Key opportunities were identified related to raising producers' awareness about existing resources with broad transferability to Vancouver Island. Opportunities are presented in this section by first identifying some of the interests and characteristics of the VIR sector that came through in the interviews, then identifying and listing key VIR potential partners for future work, and also identifying and listing the major types of resources and existing knowledge transfer channels that could be built upon.

Specific topics that producers need to be educated on, which could yield substantial benefits for relatively low effort, were identified through the integration of all project information sources and are elaborated on in Section 7.0.

6.1 Vancouver Island Agriculture Sector Interests and Characteristics

VIR agriculture is unique from the nearby Lower Mainland, which has a similar climate, due to a different mix of farm types and perspectives in the VIR. More than one industry expert stated that, in general, the VIR has a stronger interest in integrated management approaches, when compared to the Fraser Valley. At the same time, regular/dedicated pest scouting and systematic crop monitoring for pests is uncommon in the VIR. However, those that do regular crop scouting and integrated management seem to have good outcomes regarding pest control. There lies an opportunity here to document and share the pest control and economic benefits of regular pest scouting, broadening uptake of more formalized scouting practices. It is important to increase VIR producers' understanding of the importance of maintaining pests under economic injury thresholds and what these thresholds are.

A strong culture of experimentation was referenced, in the organic sector in particular. This is partially because when growers face a lack of treatment options for certain pest issues they must actively experiment with alternatives (mass trapping, controlling borders of crops, enhancing beneficial biocontrol insects). Beyond the organic sector, many farmers are willing to do small trials on-site and there is an opportunity to build upon this willingness to conduct future experiments.

In comparison to the Lower Mainland, anecdotal information suggests that on Vancouver Island there may be healthier (more diverse and abundant) wild pollinator populations and less reliance on pesticides (noted with respect to berries, but possibly applies to other growing systems as well). It was evident through a number of farm stakeholders interviewed that there is an awareness of pollinators and a desire by some to incorporate farm practices to support pollinators. Producers cited activities they are already incorporating, without external guidance or incentives, due to personal observation of what supports pollinators. Growers that are more aware of pollinators and proactive in pollinator-supporting activities could be influential in peer-peer transmission. Habitat planting for pollinators and beneficial insects could be encouraged through peer-to-peer knowledge transfer, workshops, demonstration sites and field days, and through the establishment of incentive programs. Additionally, there are many opportunities for partnerships between local conservation groups and academia to establish coordinated monitoring and research programs to provide data on benefits and optimization of habitat. Research projects could leverage existing grower habitat installation activities and grower awareness for pollinators. There are opportunities to use existing monitoring and identification Apps (such as the Insight App and iNaturalist) to engage growers in citizen science. Baseline data of pollinators and beneficial insects in the VIR, associations with habitat and crops, and economic analyses all are lacking and essential in the VIR.

Further, there are opportunities to build on existing pest monitoring that is being conducted by individual growers, private consultants, and government bodies. General, coordinated pest monitoring was flagged as a large gap in the VIR. Using existing Apps (such as iNaturalist) or other centralized systems, there is an opportunity to have those that are monitoring pests submit their observations to a centralized, public database, removing sensitive information.

Alternatively, general monitoring programs for pests could be conducted by groups already engaged in surveillance of invasive pests. Additional monitoring often does not add substantially to required resources at the field level, however, there would need to be additional funds allocated for specimen processing, identification, and databasing; areas which are often a bottleneck in monitoring programs.

Strong foundations are in place in the VIR for knowledge transfer of pest management and beneficial species support. Resources relevant for Vancouver Island (which may be underutilized- and are thus an opportunity) are documented in Section 4.2 and Appendix 3. Key VIR partner organizations follow and the resource types/common knowledge transfer channels which are currently utilized in the VIR, and are thus an opportunity to build upon, are summarized below.

6.2 Important VIR Partners

Researcher-Grower Connections

Many farmers are willing to do small trials on-site, especially for pests that are problematic. Farmers may not seek out research opportunities and researchers may not know what farmers to approach for partnerships. There is an opportunity to better connect researchers to farmers, using accessible tools like social media for posting research plans/questions to forums that farmers use.

BC Invasive Species Organizations

These organizations (both the regional coastal invasive species organization and provincial) have expertise in coordination, training and collaboration for professional monitoring and oversight of citizen science projects. The regional/provincial invasive species organizations have documented best management practices for 15-20 of the major weeds.

Farmers Institutes

Farmers' Institutes (FIs) are directly connected to producers, some have capacity to lead and administer projects, and they regularly hold growers' meetings. There is an opportunity to support and strengthen Vancouver Island FIs. Especially on Vancouver Island, where a large number of mixed farms may not belong to any particular commodity/industry association, FIs will be an important partner for any future initiatives.

IPM Crop Consultants

There are few IPM crop consultants in the VIR. However, partnering with the existing companies could help ensure this resource remains available, boost producer awareness of this resource, be a source of VIR data, and contribute to VIR-specific resources.

Non-profit Organizations

Some local VIR non-profit organizations specialize in working with farmers, supporting agri-environmental activities, and studying beneficial insects in agroecosystems. Their existing local connections with government organizations, growers, and academia, along with their in-house

research and outreach expertise are useful resources for future monitoring and/or research activities.

Honey bee groups and individual honey bee producers
Although these groups work with domesticated bee species, many have knowledge of other pollinators and are more adept than the general population at pollinator identification to coarse taxonomic levels. While working with their hives, they could be participants in citizen-science monitoring or collections of other pollinators as they move hives around to various areas, and there may be opportunities to engage them in informal, yet coordinated, pollinator monitoring.

Cost-share organizations
While there currently are very few options for growers to cost-share biodiversity support activities on farms in the VIR, there are a few opportunities for existing organizations/programs to expand into the VIR. This could include ALUS and/or Farmland Advantage which both operate a form of payment for ecosystem services. In addition, the Environmental Farm Plan Program (BC Ministry of Agriculture) currently is working to add pollinator support best management practices to their program.

Ministry of Forests, Lands and Natural Resource Operations and Rural Development (FLNRORD)
Within FLNRORD, the forestry sector monitors for invasive forest pest species. Surveying for invasive pests is part of forestry land-lease requirements. These activities could be a source of data or could include methodologies or processes to learn from. Further research is needed to explore if data gathered and methodology would be useful to the agriculture sector. In particular this applies to any invasive (or other pest) surveys done by the forestry sector at lower elevations or on the crown/agricultural interface.

Ministry of Agriculture
Producers rely on the Ministry of Agriculture for pest management support. While the direct interface between producers and the Ministry has decreased overtime with government resources moving out of traditional field extension, many producers still communicate directly with Ministry regional agrologists, entomologists, or industry specialists with their questions. The plant pathology lab is open to receiving samples from producers, which they diagnose for a small fee. There is an opportunity to educate new producers, or producers who aren't aware of these channels, of who the key contacts are within the Ministry and what services they offer. When the Ministry receives unusual diagnoses from the pathology lab, this information is shared with the relevant sector of the agriculture industry and brought to their attention via field days, the annual short course, or other means.

6.3 Vancouver Island Resources and Knowledge Transfer Channels

Stakeholders were asked how producers on Vancouver Island are currently accessing pest management information, and what they are commonly accessing. There is an opportunity to

build on already popular channels, find ways to increase use of others, and feed new and important information through these channels. Since many available resources were not developed specifically for the VIR, in order for resources to be appropriate, resources need to be able to be scaled up or scaled down depending on farm size. VIR producers need information on how to adapt the available tools to their specific challenge and context.

A few channels of particular importance to build upon, either due to their success or because they are underutilized in the VIR include peer to peer, use of private consultants, BC Ministry of Agriculture Production Guides and plant pathology lab, and a local e-mail listserv for Q&A. The full summary of stakeholder-identified popular knowledge transfer channels for the VIR follows:

- Peer to peer transmission
    - This includes informal farm chats and is especially helpful with respected and experienced growers.
- BC Ministry of Agriculture Production Guides
- Ministry of Agriculture Plant Diagnostic Lab
- On-farm demonstration
- Regional agrologists
- iNaturalist
- Report-a-Weed App in the Invasive Alien Plant Program (IAPP)
- Local suppliers
    - Through a discussion with a local supplier, it was confirmed that suppliers do not discriminate based on farm size. Farms of all sizes can develop a relationship with suppliers for information. The suppliers deal in both conventional and organic inputs and offer extension events (grower talks and meetings).
- Agriculture trade shows (Islands Agriculture Show or Pacific Agriculture Show)
    - Companies at trades shows have a lot of knowledge to share about pest lifecycles and management, both with respect to conventional and organic practices. A producer interviewee referenced the benefits of establishing an in-person relationship with suppliers at trade shows.
- Grower meetings (Farmers' Institutes, Top Shelf Feeds, Terralink)
- Other suppliers on the island (Pacific Forage)
- Private consultants:
    - VIR growers need to understand what benefits would be of paying for consultant pest management services.
- Direct contact with Ministry of Agriculture (regional agrologists, bee inspector, industry specialists, entomologist)
- Internet (Instagram, podcasts)
- E-mail listservs for troubleshooting, Q&A.
    - The COABC e-mail is very useful to growers for peer-to-peer technical support. Use of this list in the VIR specifically is unknown.
- Fraser Valley IPM newsletters

    - In the Fraser Valley, there are weekly IPM newsletters throughout the growing season for the blueberry, cranberry, and raspberry sector. Each of these newsletters is funded through a different combination of private and provincial contributions. The newsletters provide an overview of current pests of concern and provide an early warning system for growers, suppliers, and consultants. The budget for each newsletter ranges from $6,000-$10,000 and these are possible due to ties to ES Crop Consult's ongoing activities.
- Small fruit update (a partnership between Oregon, Washington, BC)
- Lower Mainland Horticulture Association short course (part of the Pacific Agriculture Show)
- Other conferences
- US university extension services
- US based information sessions
- European extension information

7.0 Implementation Priorities and Implementation Plan

7.1 Overview

This section is a high-level overview and draft of implementation priorities based on resources, research, monitoring, gaps, and opportunities as discussed throughout the report.

Three main priorities identified for the VIR are:

- Increasing grower awareness and use of existing resources
- Increasing grower knowledge of and support for implementing climate change resiliency practices (new resources to fill gaps, communication networks, extension, financial support)
- Increasing knowledge specific to the VIR including baseline monitoring and field research

Implementation and Climate Change Resiliency

As summarized in Section 3.0, the anticipated direct and indirect effects of climate change on pests, their natural enemies, and pollinators, and the interactions with climate change on relevant crops or host plants, are extremely complex to model and predict. The scientific literature and experts in the field confirms this, and not all producers will have the time or capacity to become experts nor to digest this cascading information. In addition, effects of climate change will be regionally specific, and information will vary in applicability among regions. For these reasons, any planned implementation activities should be framed around farm system resilience and should include local monitoring and research. Generally proven and theorized mitigation and adaptation to climate change impacts such as building in farm resilience in the form of diversity inclusion and support, redundancy, and risk mitigation practices are important implementation priorities. In addition, resilience and adaptability can be

enhanced by having strong networks of collaboration and support/capacity in place to address challenges when they arise.

The implementation priorities recommended are based around these resiliency principles. The priorities speak to ensuring producers are accessing the information that is currently available, that farmers are well-connected to their peers and support organizations, that farmers are supported to continue to learn and experiment, and that new knowledge and additional resources are put into place to fill the most striking gaps.

Existing Resources

Communications activities are required to ensure VIR producers are aware of and utilizing the best existing resources and tools for pest management of their crop type(s). A list of key existing resources for knowledge transfer is provided here.

- Increased awareness and uptake of the Ministry of Agriculture Plant Health laboratory services (especially by central and northern VIR producers, and by commodity groups who are currently submitting fewer samples).
- Ensure farmers have Ministry of Agriculture contact list of experts, foster face-to-face or personal connection with Ministry expertise.
- Work with the BC Agriculture and Climate Adaptation Research Network (BC-ACARN) to connect pest researchers to VIR farmers for field trials.
- Provide links and training to use reporting apps (especially for monitoring)
- Curate info from elsewhere for VIR for extension:
    - From Fraser Valley research and projects: Have a specialist conduct a review of this large inventory for transferability to VI and identify which completed projects lack extension.
    - Where crop-specific gaps exist, complete expert curation of IPM information from elsewhere (US, Europe, Eastern Canada) for applicability to the VIR.
- Encourage and support small farmers to access supplier-provided information via trade shows or direct relationship with supplier, if not already.

Monitoring and Research

Implementation of standardized and coordinated monitoring is a priority for pests, beneficial biocontrol insects, and pollinators. Having baseline data and data to inform associations with habitat, landscapes, and agricultural practices will help inform priorities and strategic support of resilient beneficial insect communities. Similarly, local research that can help inform biocontrol strategies and pollinator support in the unique VIR and demonstrate cost-benefit of strategies to optimize production and inputs are priorities. Researcher-producer dialogue is needed to identify specific research priorities and questions for the VIR. These data can be used to create VIR-focused resources to fill gaps around emerging issues and underserved agricultural sectors.

Climate Smart Agriculture and IPM

'Climate-smart agriculture' (CSA), as promoted by FAO (http://www.fao.org/climate-smart-agriculture-sourcebook/en/), is an approach that is receiving a lot of attention recently. CSA aims to reorient entire agricultural systems in order to support development and ensure food security in a changing climate. Within this approach, IPM is recommended as a sound pest management strategy meeting the aforementioned overarching CSA goals. In order to increase IPM practices in the VIR, the following broad areas of activity are recommended:

- Education and awareness of pest scouting practices, economic injury thresholds and cost-benefit of obtaining consultant support or systematic scouting/field monitoring.
- Crop-specific IPM education, workshops, training.
- Create VIR-specific IPM overview/early warning newsletters similar to those in the Fraser Valley.

Development of these resources should occur in partnership and consultation with local growers and using information from VIR farms when possible.

Producer Networks

Support and encourage producer networks and peer-to peer knowledge transmission through the following:

- Coordinate a VIR farmer listserv to connect small farmers for trouble shooting (similar to the COABC, but specific to VIR). A strong FI could run this with modest financial support.
- Support FIs or established/respected producers to attend trade shows/conferences.
- Support FIs for community-based and field-based extension (since VIR farmers are less likely to travel to large trade shows off island, and many don't belong to commodity groups).

Ecosystem Services and Habitat Integration

In addition to IPM being a cornerstone of FAO recommended practices for CSA, enhancing ecosystems and their service provision capacity to agriculture is fundamental to CSA. Building resilience into agriculture can be advanced by integrating ecosystem service providing habitat into agricultural landscapes to build system resilience to climate change. To increase ecosystem service resilience and provision in the VIR, the following broad areas of activity are recommended:

- Increase awareness among growers of ecosystem service provision benefits (CBC and pollination) through network communication and peer-peer communication. This could include government funded workshops, field demonstration, and resource creation.

- Support growers in habitat restoration and integration through cost-share and technical guidance, with an emphasis on the climate benefits of native habitat. Existing programs such as the Environmental Farm Plan are adding pollinator supporting BMPs and this should be promoted in the VIR. Other programs, not yet active in the VIR, such as ALUS and Farmland Advantage, should be explored for the VIR.
- Beneficial insect monitoring and collections should be initiated in the VIR and patterns in species composition, abundances, and crop services in relation to landscape and farm practice variables should be initiated. Enhancement of capacity for specimen processing, identification, and databasing is needed.
- Research in the VIR into ecosystem service provision in relation to landscape and farm practice variables should be initiated. This would provide a better understanding of current beneficial insect communities in the VIR, their contributions to production, and associations with farm and landscape variables. Research in the VIR should involve partnerships with growers, be conducted on working farms, and include cost-benefit analyses.

7.2 Proposed Project Components

This is an outline, for discussion purposes, addressing gaps outlined in this report and built around the implementation priorities based on the totality of information within this report. Plan elements listed and described below can be stand-alone projects, combined, and scaled up or down depending on available resources and desired implementation time frame. Many elements are synergistic, and are mutually reinforcing - the uptake and impact of certain activities would be much greater when/if combined with certain other activities to form a multi-faceted project.

Grower education/use of existing resources

The primary gap that was identified and is therefore a priority for implementation was grower knowledge and use of existing resources, and education for growers on climate change mitigation for pests and beneficial insects. Below are 4 projects addressing this main gap and priority.

1. IPM training pilot for small to medium mixed farms

Rationale: IPM is recognized as being one of the most important strategies for mitigating the effects of climate change on pest pressure in agriculture; yet a gap was identified in the VIR on grower understanding and implementation of IPM techniques. This gap is most prominent among small-medium mixed farmers who are less likely to belong to an industry group or to invest in privately delivered expertise. There is a need for more direct training of individuals, peer-peer knowledge transfer, demonstration, and ongoing troubleshooting and support.

Description and Partners: This project could leverage existing resources and other CAI projects underway (ES Cropconsult/FAIP project underway on Implementing Integrated Pest

Management Practices on Small-Scale Farms) to create a training manual for IPM for mixed farms in the VIR. This could involve presentations and workshops on-farm in the VIR coordinated through FIs (including funding to FIs for their logistical and outreach support). The pilot would develop and test the training manual/delivery method to a modest audience, which could then be refined, and delivery broadened in the future after evaluation. In-kind contribution of Ministry of Agriculture staff time to travel to workshops and participate would be required. One of the private IPM consultants located on VI would be well-positioned to coordinate or contribute to project delivery.

2. Training and support for habitat integration to support beneficial insects

Rationale: Another cornerstone of adaptation to new and emerging pest issues and pollination deficits in relation to climate change is support of wild biocontrol and pollinating insects in agricultural landscapes. Robust and diverse populations of biocontrol insects and pollinating insects can help ensure pest control and pollination services in a changing climate and they are best supported through habitat creation and/or habitat management in agricultural landscapes (in addition to incorporating IPM practices on farms). The lack of awareness of habitat benefits to pest control and pollination, and lack of technical support and awareness of resources were identified as large gaps in the VIR.

Description and partners: Training with technical and practical information on creating and maintaining habitat for beneficial insect communities. Could involve workshops and/or a resource and rationale awareness campaign. Demonstration habitat and site visits, and peer-peer knowledge transmission should be included. This program could leverage existing workshops/outreach material such as the Island Pollinator Initiative (IPI) habitat creation 10-part webinar series specific to the VIR, and Pollinator Partnership Canada and Habitation Acquisition Trust resources. Advancing cost-share programs through a group such as ALUS or Farmland Advantage for habitat creation could be part of this program or part of one of the research programs described below.

3. Pest Management Knowledge Transfer Series

Rationale: Extension often comes up as the most prominent gap for the agriculture sector. This is no different in the realm of pest management. A knowledge transfer series on Vancouver Island focused on pest management could be seen as only a short-term solution, but if done well and accompanied by distribution of lasting resources, and formation of knowledge networks/relationships, this activity could be of great value to current and future producers.

Description and partners: This project would curate the most valuable information (per the recommendations in this report and the Existing Resources listed in Section 7.0) for the VIR audience and would share fairly high-level information through a series of FI presentations, a large workshop (Islands Agriculture Show), or a series of field days. The focus would be less specific than project #1 and would be more about where to find existing resources.

Managing viruses and diseases requires a different set of tools than addressing other pests and expertise on viruses/diseases is limited on Vancouver Island, so this could be an area of focus. The Ministry of Agriculture plant health lab would also be featured. This would help with virus/disease management if more people understood possible viruses and indications, and where to test. In addition, if more farmers used this resource in the long run it could contribute to detecting emerging pests more quickly.

4. Creation of VIR grower community

Rationale: while there are various listservs and grower groups that span the VIR, there is no community (online, or otherwise) inclusive of all VIR growers. A lack of awareness of available resources was identified as a primary gap in the VIR and could be addressed through a platform (small such as a pest-focused Instagram feed, a listserv, newsletter, or something more in-depth) with wide VIR subscription. This would need to be combined with increasing opportunities for VIR growers to connect in-person. A new platform could be either workshopped or launched at an event such as the Islands Agriculture Show. Addressing other priority gaps in the VIR (such as training, research) also would be aided by having a centralized platform for grower information exchange.

Description and partners: An online discussion group and/or listserv would be a relatively simple platform to create. Wide advertisement and a well-rounded and in-depth communications plan would be necessary to get subscription from as much of the farm community as possible in the VIR. The platform could be used to list and link to available resources for farmers in the VIR (Appendix 3 in this report could be used as a basis for populating the resource summary). The platform could be hosted by an Industry Association, Farmer's Institute or other sector group (such as the Islands Agriculture Show Society) and should include many avenues/partners for advertisement.

Monitoring

Monitoring for pests of concern (current and potential) is done by the Ministry of Agriculture and the CFIA. These monitoring programs are targeted, and many interviewees expressed that they are important and should continue, and they generally are adequate. The highest priority identified with respect to monitoring is to initiate more broadscale monitoring for pests to understand baseline populations and detect potential problems (new pests or outbreaks) sooner. There is very little monitoring of pollinator populations in the VIR (and none that is specific to agriculture). There is no agriculturally relevant coordinated monitoring of beneficial species. Below are 3 potential projects that bolster existing detection/monitoring and/or initiate new detection/monitoring activities.

1. Crop-based comprehensive monitoring

Rationale: Many of the highest ranked pests of concern (animals, diseases, weeds) are not currently monitored. However, the resources required to initiate truly comprehensive monitoring across a geography as varied as the VIR, including the many production types, would be truly staggering. If arranged by crop type, it is feasible to do comprehensive monitoring at a small sample of sites that includes numerous pests using various trap types detection methodologies/lab sampling and also include monitoring for associated beneficials species, and/or soil biodiversity.

Description and partners: This project would begin by selecting 1 or 2 crop types to focus on as a pilot, potentially looking at berries or tree fruits on the Saanich Peninsula or Cowichan Valley and forage on mid-Vancouver Island. The first step would be to flesh out the provided list of potential future threats, by completing additional interviews related to the crop type and the addition of mapping (see Priority Pests of the Cariboo-Chilcotin BEC zone methodology). Once a refined list is complete for the chosen crop type(s), sites and collaborators would be needed, following the model used for the Ministry's true armyworm monitoring. Soil biodiversity could also be measured at these sites using pitfall traps based on recent Ministry of Agriculture work.

2. Comprehensive monitoring program

Rationale: As described under project #1 above, the resources required to initiate comprehensive monitoring across VIR would be large. This project would begin that process (for easily identified insect pests and weeds) by using existing networks and existing reporting resources.

Description and partners: Similar to project #1, the project would begin by fleshing out the list of potential future threats from our research by completing additional interviews/surveys combined with climate change mapping (similar to the Priority and Emerging Pests of the Cariboo-Chilcotin methodology using climate projections of BEC zones). Once a refined list is in place, resources would be sourced or developed for education on identification of priority species and awareness/education on how to use the associated reporting apps. Reporting apps would be verified to include all of the pests of interest. Once that project infrastructure is in place, an Island -wide (or ⅔ of island) monitoring program on agricultural land would be piloted using a combination of Ministry, citizen-science, hired summer students, and private IPM consultants, with a contractor hired for coordination.

3. Targeted priority pest species monitoring

Rationale: Current and recent Ministry of Agriculture programs are monitoring for presence/absence of major pests of concern on Vancouver Island including: grape phylloxera (regulated pest), true armyworm and western corn rootworm. The ability to collaborate on pest monitoring activities differs whether a pest is regulated or not, and there are more opportunities for the private sector to bolster activities for un-regulated pests. Two options follow to increase targeted, species-specific monitoring. The first option would be to increase monitoring and outreach efforts pertaining to pests that the Ministry has already been monitoring for in the VIR,

and the second would be to begin monitoring for new emerging pests in the VIR.

Option A) Description and partners: This project or project element, would continue the armyworm and western corn rootworm monitoring completed by the Ministry of Agriculture over the last few growing seasons. The same sites would be maintained with the addition of a few more sites in the Courtenay/Comox area. Project success would be dependent on utilizing the same partners, contractors, and collaborators as in previous years. The cost would be relatively low to add presence/absence monitoring for 1 or 2 other species that can be caught using the same trap type (wireworm?).

Option B) Description and partners: Option A species-specific monitoring could be expanded to include monitoring for additional pests that are not currently monitored for but that are of very high concern regionally or provincially such as spotted wing drosophila or brown marmorated stink bug. Alternatively, monitoring for these species could be initiated in lieu of pests already monitored by the Ministry of Agriculture if their previous work should continue.

4. Baseline pollinator population assessment in the VIR:

Rationale: There is almost no information on pollinator populations in the VIR in relation to agriculture. Robust and diverse pollinator populations are required for pollination of many crops in the VIR including berries, some tree fruits, and some vegetables. Healthy wild pollinator populations can help reduce reliance on managed honey bees (which are becoming less reliable with increasing health problems and they are not the best pollinators of many crops) and mitigate against expected impacts of climate change on pollination. Understanding baseline populations and associations is a first critical step in conserving/enhancing pollinator communities.

Description and partners: Monitoring/collecting pollinators could be done across a wide range of agricultural and associated habitat in the VIR in order to get baseline data. This could be conducted as aerial netting for pollinators across the VIR at times of flowering in crops and in associated habitat and/or with passive trap sampling. The monitoring should be led by researchers but could incorporate citizen scientist participation. The CAI Bulkley-Nechako and Fraser-Fort George baseline pollinator assessment could be used as a model for the VIR monitoring. Capacity for specimen processing, identification, and databasing is needed. Local or nearby universities (UVIC or UBC) would be possible partners as well as VIR-based non-profit organizations already leading research and citizen science data collection programs.

Research

Research specific to the VIR was generally not identified as a priority since research from other regions can apply to the VIR. However, in the case of habitat support for beneficial insects, many interviewees did identify a gap and a need for regionally specific research to better understand pest and beneficial associations with habitats, landscapes, and plant species in the

VIR. We identify 3 research projects below that address areas where regionally specific research would be valuable.

1. Maximizing beneficial insect support

Rationale: As mentioned above, supporting diverse populations of beneficial pest control and pollinating insects is essential for climate change mitigation in agriculture. As identified above, there are gaps in grower awareness of resources and benefits related to supporting beneficial insects. However, in addition, there also are gaps in the VIR on beneficial insect associations with habitat specific to the VIR and practices for habitat optimization to best support diverse beneficial insect populations. While there is information from other regions, unique habitats and plant-beneficial associations in the VIR make regionally specific research and information essential for wider uptake and understanding of systems and optimization. Local research and knowledge would help growers be more confident in best techniques and benefits.

Description and partners: Research on associations of biocontrol insects and pollinators with landscape and habitat variables. This research could be done without creating new habitat--either along gradients of land types/use (correlative) or as an experimental/control design (and possibly include partnering with a cost-share group such as ALUS or Farmland Advantage to subsidize new habitat). Experiments on and monitoring of general pest abundance, diversity, and damage in a crop(s) and pollinator abundance in relation to habitat could be conducted. This project could include a literature review on beneficials that control pests of interest in the VIR and habitat support value to control those pests and pollinators.

2. Cost-benefit analyses of habitat support for biocontrol and pollinator insects

Rationale: growers often do not understand or are not convinced of potential financial benefits of habitat creation to support ecosystem services. In addition, costs and benefits of practices such as beneficial insect habitat creation or maintenance are very regionally specific, making local information and demonstration a key component of optimization and uptake. This area of research was of strong interest to participants in the Vancouver Island Regional Adaptation Strategies planning process.

Description and partners: While the above proposed research project (#1) would generally assess pests and beneficial insects in habitat and adjacent crop(s), research could be more targeted to assess cost-benefit of ecosystem service provision from habitat integration in one crop or for few crops. In the VIR, there are many small, mixed vegetable farms, and costs and benefits of habitat incorporation into these systems was identified as a regional gap. As above, the research could be done by selecting existing habitat that has already been created on farms and pairing with control sites. The assessment should include full cost analyses of habitat creation and maintenance in comparison to alternative land management or crop production. Financial benefit of ecosystem services should be assessed through quantification of pollination benefits (to pollinator-dependent crops on the mixed farms) and pest control benefits (damage,

treatment necessity), and analyses of cost savings to create a cost-benefit models with a temporal component.

3.Targeted pest-crop control (habitat biocontrol/IPM) experiments

Rationale: The report flags an opportunity for research/farmer partnerships in the VIR for on-farm applied research experiments. While experiments on this topic from other areas would likely apply to the VIR, there is a lack of research on this particular topic in general, so VIR-based research could begin to address this gap locally and also be valuable elsewhere. Habitat is very regionally specific, as are the beneficial insect communities, so VIR could initiate this work or be one site in a broader study (possibly under the leadership of a university like UBC, since they have more capacity for this type of research than any VIR-based academic institutions).

Description and partners: Identify and approach project lead researchers with an interest in bio-control research. Partners could include COABC, UBC, BC-ACARN, Kwantlen University, AAFC and producers or farmers groups such as FIs or the PAAC. Set up on-farm experiments to research targeted biocontrol and/or IPM control of specific pests in specific crops of concern in the VIR (for example, SWD in soft fruit, true armyworm in cereal/hay crops, or wireworm in root crops, or cereal crop roots). Selection of crop types and pests for these experiments could be drawn in part from learnings from the ES Cropconsult/FAIP project underway on Implementing Integrated Pest Management Practices on Small-Scale Farms and from further consultation with selected researchers.

7.3 Sample Near-Term (2 year) Project

An initial set of near-term projects was developed based upon section 7.2 of this report, combined with discussions between, and feedback from, the Project's Oversight Committee. Further consultation with the Climate & Agriculture Initiative followed the POC input, focused on the Regional Adaptation Program timelines and delivery mechanisms. The consultants also obtained further information on potential synergies or overlap with anticipated BC Ministry of Agriculture Food & Fisheries pest monitoring activities in the VIR.

This initial set of 2 unique projects was then combined into a single 2-year project, which is more comprehensive in terms of the range of activities covered, but smaller in both scope and budget than the original set of projects. In terms of filling the identified gaps and opportunities, the ideal approach, would still be to deliver multiple projects, employing different skills and resources for each project. However, consideration of programmatic constraints including capacity for pursuing multiple funding sources, timeline and budget limitations have resulted in the following hybrid project, which should also be valuable and successful with the appropriate diversified team in place.

Project: VIR climate-smart agricultural pest management and beneficial insect support

Proposed Timeline: March 2021 - March 2023

Executive Summary:

This project combines aspects of a number of the project elements outlined in section 7.2. It includes:

- IPM training and producer-led monitoring support for VIR farmers
- Broad monitoring on a sample farms of pests, beneficials, pollinators. Focusing on farms with fruit and berry crops
- Clustered monitoring in 2 different regions of the VIR, with each area having approximately 10 monitoring sites for a total of approximately 20 sites
- Real-time/in-season communications to growers of monitoring results
- Analyses of local and landscape characteristic associations of pest and beneficial populations using GIS landscape classification and site evaluation, and
- Project results knowledge transfer

Both grower knowledge of existing resources and understanding and implementation of IPM techniques (with an emphasis on the importance of regular scouting), were highlighted as priority gaps in the VIR. Conducting commodity-specific grower IPM training sessions will address both these gaps by presenting existing resources and providing practical, VIR-specific information to growers on IPM, a critical tool for climate change adaptation in agricultural production.

Broad monitoring/collections of pests, pollinators, and biocontrol arthropods was identified as a primary gap in VIR. These collections will provide baseline data on a wide range of pests and beneficials that are associated with agroecosystems in the VIR and preliminary information on habitat (local and landscape) associations. These data are important for forming an initial understanding of current populations and how agricultural systems can be optimized to support robust communities of beneficial insects that can help to enhance farm resilience to changing pest populations and support robust pollination services.

In addition to being used for this project, data can be used to track changes in insects over time, combine with other VIR datasets to provide a fuller picture of occurrences and abundances in the VIR, and potentially be used by researchers doing meta-analyses of insect populations over larger regions.

Although the proposed number of monitoring sites/locations will necessarily be small pest monitoring throughout the season, on this targeted selection of sites, can be tied to regular communications with growers on what is being found and how this might apply to their pest management. End of season, and end of project, results from the broad monitoring will lay a

foundation for future work addressing other key gaps/opportunities from the report such as: habitat demonstration projects, applied research, and expansion of monitoring to additional sites or crops.

Specimen storage and databasing options should be assessed to ensure that the specimens are housed for long-term reference and that the associated data meet current insect databasing information standards and are widely available (to researchers and possibly in a public database such as GBIF). Options for long-term specimen storage and decisions on databasing, so that there is wide access to the data, should be made by an experienced professional in consultation with partners and the POC. Data and/or a subset of specimens of pollinators, pests, and biocontrol insects likely would be of interest (collections and/or data) to the Royal BC Museum, the Royal Saskatchewan Museum and potentially others.

Components:

1. IPM training for VIR farmers

IPM training will leverage existing resources and other CAI projects (i.e. Implementing Integrated Pest Management Practices on Small-Scale Farms). Existing IPM material will be curated to create 2 similar IPM training sessions (forage and berry/fruit) for the VIR (both conducted in year one and a second set in year 2. Year 2 program should adapt and improve from feedback from year 1). Forage is suggested as a focus to complement on-going Ministry of Agriculture forage pest monitoring and address the request of forage producers outside of the Ministry program to conduct their own monitoring. Berry/fruit crops are suggested to correspond with the focal area of activity 2. Training could be disseminated through virtual sessions, in-person farm visits, or a hybrid.

2. Monitoring pests and beneficials on mixed farms (including analyses of local and landscape associations)

This activity includes monitoring on mixed farms using standardized collection methodologies such as sweep netting (pests and biocontrol insects), pitfall traps (pests and biocontrol insects), sticky cards (pests and biocontrol insects), aerial netting (pollinators), pan traps and/or blue vane traps (pollinators). 10 farms in each of 2 locations across the VIR for approximately 20 collection sites. Collections will occur in crops (1-2 crop types, likely berry/tree fruit occurring on the same farm) and in adjacent crop habitat using standardized, and best (current) monitoring practices (effort and other methods standardized) in order to make comparisons among collections and sites. This activity also includes GIS landscape classification within a 1km radius of each farm and farm habitat characteristics analyzed in relation to collections to better understand insect population associations with local and landscape factors.[4]

[4] While the selected project contractor will determine methodological details, some recommendations follow. All specimens must be preserved, labeled, and databased using best practices. Specimens will be identified to species where possible (pests and biocontrol insects), with bee species identifications to species (name or morphospecies) for at least 90% specimens. A project report including species identifications, abundances, group richness, and habitat analyses results will be required.

3. In-season grower communications

Communication to nearby growers will occur who would benefit from information gathered at the monitoring sites. At a set frequency throughout the season (potentially bi-weekly) or, alternatively, driven based on discovery of important pest observations/information, growers of berries/fruit in the surrounding region could sign up for pest monitoring updates related to findings from the monitoring sites. To enable this, early in the project timeline the project will need to be announced and widely promoted through all possible channels and a broad contact list will need to be developed. These grower updates could be completed through a simple e-mail list.

4. Resource development and reporting of results

Reporting of project results will be conducted upon completion of the final report. Monitoring information will be distilled and presented as a report for a lay-audience. In addition, summary outreach material should be created from results in the form of a fact sheet for application of findings for the farm management and farm activities. The report and associated resources can help inform future initiatives to raise awareness of pollinator/beneficial control species and to increase uptake of beneficial insect support. The project budget and activities recommend a modest amount of resourcing for sharing the results and applied resources, this could be done through attending grower meetings, holding webinars or other. This time could also go towards ensuring the monitoring datasets are publicly available and that researchers are aware of these data.

Objectives:

- Overall: Increase farm resilience to climate change through training and knowledge transfer, baseline beneficial/pest information, and preliminary information on habitat (landscape and local farm) associations
- Increase grower understanding and implementation of IPM techniques
- Increase grower knowledge and use of existing IPM and beneficial insect support resources
- Baseline data of pests, biocontrol, and pollinating insects in sections of the VIR
- Preliminary information on pest and beneficial population local and landscape associations
- Transfer project results to growers and other stakeholders to make more informed decisions on BMPs for beneficial insect support

Activities:

1) Create collection protocol for pest, biocontrol, and pollinator insects using current best practices in consultation with local experts, and select sites for collection in consultation with Farmers' groups (Mar - Apr 2021)

2) Year 1 insect collections (late Apr through Aug 2021)

3) Creation of communications channels / project awareness raising and in-season grower communications (May/Jul 2021- Oct 2021)

4) Develop and deliver IPM training sessions (2 commodity-specific versions) delivered as live online webinars, in person group sessions on a working farm, or a hybrid. IPM resources will be curated for the training and distributed to participants (virtually) leveraging current resources (Jun 2021 -Sept 2022)
    a) One training version will be forage focused to complement Ministry of Agriculture forage pest monitoring activities for producers who are keen to implement their own monitoring
    b) One training version will focus on berry/fruit crops to complement this project's monitoring component.

5) Process, curate, database, and identify yr 1 collections (May 2021-Dec 2021)

6) Re-confirm sites and partners for Year 2 monitoring and collaborator training/communications (Winter/early spring 2021/2022)

7) Year 2 insect collections (Apr through Aug 2022)

8) Year 2 specimen processing, ID, and databasing (May 2022-Nov 2022)

9) Deliver second set of IPM training sessions, or deliver 2 new sessions focused on pollinators and beneficial insects (Summer- Fall 2022)

10) Results analysis, resource development (Oct-Dec 2022)

11) Final report Jan 2023

12) Knowledge transfer re: findings (Jan-Feb 2023)

Suggested Deliverables:

- 2 IPM training sessions (one focused on forage, one on berry fruit) each year (and training resources), for a total of 4 training sessions
- In-season communications (e.g. 5 e-mail updates or newsletters to growers)
- Interim year 1 report
- Specimen dataset (year 1 and 2)
- Results reporting (e.g. fact sheet, results summary for growers)
- Final report

Budget:
Year 1: $68,300

Year 2: $77,110

Budget summary

Activity	***Cost***
Year 1	
Project set-up	***$5,000***
Monitoring (including collections, identification, and databasing)	***$45,500***
Communications	***$1,000***
IPM training	***$8,600***
Results and Reporting	***$2,000***
Admin (10%)	***$6,200***
Total (incl GST)	***$68,300***
Year 2	
Project set-up	***$1,600***
Monitoring (note, yr 1 could be slightly reduced in scope and yr 2 increased for total monitoring being $91K)	***$45,500***
Communications (includes yr2 knowledge transfer)	***$2,900***
IPM/ other training	***$4,600***
Results and Reporting (landscape analyses, data analyses, report-- technical and outreach)	***$15,500***
Admin (10%)	***$7,010***
Total (incl GST)	***$77,110***

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Appendices

Appendix 1: Questions for key stakeholders presented as an online form and through phone interviews

1. What current or past activities is your organization/are you engaged in related to agricultural pest and/or beneficials research/monitoring/surveillance and management in the last 5 years (with focus on activities on Vancouver Island)?
a. Region
b. Crop(s) and/or Pests
c. Years of study
d. Data availability/Reports/Summaries
e. Publications
f. Key Contact
2. How do you survey for pests and pollinators on your property or in crops that you manage
3. In addition to your own work, do you have knowledge of other groups or individuals that are surveying/monitoring pests in your industry?
a. E.g. (prompts/options): Area-wide surveillance for one or more pests, CFIA, Private consultant (third party), In-house IPM staff person, Owner-operator, suppliers, farmer, No one, Other
4. From your perspective, what are the main rising concerns (insects, weeds, diseases, and invasive species) in your industry?
a. Please name any pests you are aware of that are not yet detected in VI which are threatening your industry elsewhere.
5. What do you see as largest gaps in understanding of pest pressures on Vancouver Island?
a. E.g. (prompts/options): Knowledge (identification, range, lifecycle) of main pests, threshold treatment levels, grower extension, pesticide selection/efficacy, biocontrol feasibility, other non-chemical control
6. What do you see as the largest gaps in knowledge/understanding of biocontrol insects?
a. E.g. (prompts/options): knowledge of predator/parasite communities, effectiveness studies, habitat support
7. What do you see as the gaps in knowledge/understanding of native pollinators on Vancouver Island?
a. E.g. (prompts/options). habitat support, main pollinators of ag on island, optimizing support/plantings, crop reliance on pollinators, efficiency of diff pollinators, pesticide impacts
8. What resources do you or others in your industry use for pest management information?
a. Provide titles, links, organizations etc.

9. Do you know of other organizations, researchers, private consultants, and/or industry (E.g. chemical, seed, biocontrol suppliers) that are engaged in a. research, b. surveillance/monitoring, and/or c. management of pests and/or beneficial arthropods in agriculture on Vancouver Island?
If so, please provide organization and contact name and email, and publications/links if available
10. What do you think would be the most productive and efficient way to expand on current monitoring/research efforts or to address the gaps identified in the previous questions?
a. Groups that have capacity-- which ones
b. Funding sources
c. Coordination (how, by whom)
d. Centrally driven (e.g. co-ordinated by experts) or Citizen Science (informal network/ producer driven) or Hybrid

Appendix 2: Interviewee list with names, affiliations

Name	Organizations	Production Type/Role
Completed Interviews		
Adrian Arts	Tree Fruit and Grape Specialist, Ministry of Agriculture	Tree Fruit/Grape
Bonnie Zand	IPM consultant (Fanny Bay)	All crop/IPM
Brad Chappelle	Heart of the Valley Angus (via Comox Valley Farmers' Institute)	Forage/Livestock
Carolyn Teasdale	Industry Specialist-Berries, Ministry of Agriculture	Berries
Claudia Copley	Royal BC Museum, Entomology Collections Manager	Entomology
Conrad Berube	BC Ministry of Environment, IPM officer, Nanaimo	All crop/IPM
Don Hare	Coastal Invasive Species Committee	Invasives
Elizabeth Elle	Simon Fraser University	Plant/Pollinator relationships
Eric Gerbrandt	Research Director, BC Blueberry Council, Raspberry Industry Development Council, BC Strawberry Grower's Association	Berries
John Buchanan	Vancouver Island active member, BC Forage Council	Forage/Livestock
John Holubeshen	Nanaimo Beekeepers	Honeybees
Karina Sakalauskas	Organic Specialist, Ministry of Agriculture	Organics
Kiara Jack	Environmental Farm Planner (Island) Formerly ES Crop Consult	Cannabis/IPM
Paige Erickson-McGee	Habitat Acquisition Trust	Pollinators
Paul Warkentin	Terralink	All crop
Siva Sabaratnam	Plant Pathologist, Ministry of Agriculture	Pathology

Name	Organizations	Production Type/Role
Stan Reist	BC Honeybee Producers' Association	Honeybees
Tracey Hueppelsheuser	Entomologist, Ministry of Agriculture	Entomology
Focus group with Peninsula Area Agricultural Committee		
Beverly Marley	Marley Farm, Small mixed crop/livestock farmer	Mixed farmer
Larry Sluggett	Sluggett Farm, Mixed farmer	Mixed farmer
Phillip Christie	Small orchardist and mixed	Mixed farmer/tree fruit
Robin Tunnicliffe	Sea Bluff Farm, Mixed farmer and cooperative buyer	Mixed farmer/Organics
Terry Mitchell	Mitchell Farm, Large mixed crop/livestock farmer	Mixed farmer
Survey respondents and written replies		
Andrew Simon	Galiano Biodiversity (and University of Victoria MSc on bumblebees)	Climate change and pollinators
Bejay Mills	Dynamic Ecosystems Crop Protection	All crop/IPM
Crystal Arsenault	Administrative Director, Islands Organic Producers Association (IOPA)	Organics
Dean Moraes	Field and Greenhouse Supervisor, Canadian Food Inspection Agency	All crop/pests
Edgar Smith, PAg	Beaver Meadow Farms/Natural Pastures	Forage/Livestock
Gary Telford	Knowledge Tech Transfer, Agriculture and Agri Food Canada	Research/Extension
Heather Meberg	ES crop consult	All crop/IPM
Jennifer Williams	Associate Professor, University of British Columbia	Climate change and species distribution
Josie Roberts	Entomology Biologist, Canadian Food Inspection Agency	Entomology
Paul VanWestendorp	BC Provincial Apiculturist, BC Ministry of Agriculture	Apiculturist
Andrea Shaw	BC Ministry of Agriculture	Agroecologist

Appendix 3: Research and Resource Scan

Title/contact/author	Organization	Description	Created for BC and/or Pacific Northwest	Created specifically for the VI region
Research/ Resources Underway				
An emerging biofungicide for grey mould control in strawberries-Trichoderma. Dr. Michelle Franklin	Kwantlen Polytechnic University- Institute for Sustainable Horticulture/ Agriculture and Agri Food Canada		yes	no
Determining Optimal Wildflower Patch Arrangements to Minimize Pollination Deficits in Cultivated Blueberry: Dr. Rebecca Tyson, Associate Professor,	University of British Columbia.	Developing mathematical models of bee behaviour within blueberry fields to determine optimal placement of wildflower patches to foster native bumblebee populations.	yes	no
Developing a decision support system for mitigating fruit rot diseases of berries: Dr. Rishi Burlakoti, Research Scientist,	Agassiz Research and Development Centre, Agriculture and Agri-Food Canada	Developing a decision support system based on weather station data and predictive models of disease life cycles. Isolating and characterizing bacterial blight will be used to develop better screening protocols for the breeding program so that resistant cultivars can be bred for BC and to facilitate evaluation of alternatives to copper-based products to diversify field-management options.	yes	no
Development of Molecular Diagnostics for Plant-Parasitic Nematodes in BC: Dr. Tom Forge, Research Scientist,	Agriculture and Agri-Food Canada	Developing a lab method for detecting nematodes in soil and root samples, filling a gap at BC Agri in diagnostic capacity for the industry.	yes	no
Development of PCR Based Methods to Reliably Distinguish Shock or Scorch Virus Infected Blueberry Plants. Dr. Jim Mattsson, Associate Professor	Simon Fraser University	Determining strain variation for blueberry shock and scorch viruses to improve reliability of diagnostic tools available to the industry.	yes	no
Dr. Leonard Foster	University of BC and Industry	Leonard Foster's lab studies key pathogens such as the varroa mite and Paenibacillus larvae. Honey bee molecular biology (protein and peptide mapping). Genome annotation using proteogenomics methodologies.	no	no

Ecological Pest management for Spotted Wing Drosophila: Dr. Juli Carrillo, Assistant Professor	University of BC and Industry	Developing alternative methods of SWD control to reduce regional pressure and reliance on chemical tools, including evaluation of intercropping options to repel SWD, developing better attractants for lures and traps, and establishing effective biological control species in the region.	yes	no
Effects of Host, Pathogen, and Environmental Factors on Increased Incidence of European Foulbrood in Honey Bee Colonies Pollinating Blueberries in BC. Dr. Sarah Wood	University of Saskatchewan	Determining effects of common pesticides on bee susceptibility to European foulbrood disease and assessing ways to improve bee nutrition and health.	yes	no
Emerging cutworm controls options- Beuveria Bassiana; Beuveria Assay and Entomopathogenic nematodes (EPNs). Dr. Michelle Franklin	Kwantlen Polytechnic University- Institute for Sustainable Horticulture/ Agriculture and Agrifood Canada		yes	no
Evaluating mass trapping as a tool for non-chemical spotted wing drosophila management: Allyson Kang, IPM Consultant,	ES Crop Consult Ltd.	Evaluating mass trapping as an option for reducing SWD pressure in conventional and organic settings.	yes	no
Evaluation of spray-induced gene silencing of blueberry scorch and shock viruses as a method to reduce virus number and symptoms of infected blueberry plants: Dr. Jim Mattsson, Associate Professor,	Simon Fraser University	Designing a biopesticide that can be used to prevent the spread of economically important blueberry viruses.	yes	no
Heather Higo	University of BC (Beehive Research Cluster)	Has worked on bee IPM, BeeOmics, and Bee Health in Blueberry projects, and is currently back at SFU managing a bee research field project testing a potential new miticide with chemist Dr. Erika Plettner. Other research interests include honey bee health, pathogens and pests; blueberry pollination and effects of agriculture management on pollinators; and queen breeding and overwintering.	no	no
Implementing Integrated Pest Management Practices on Small-Scale Farms: Marjolaine Dessureault, Research Director,	ES Crop Consult / Farm Adaptation Innovator Program	Project will develop a series of IPM resources, including fact sheets and workshops. Fact sheets underway include: spider mites curcubits, powdery mildew curcubits, powdery mildew strawberries, yellow rust, two-spotted spider mites berries, tuber flea beetle, carrot rust fly, downy mildew in onions, caterpillars in small fruit, cole crop caterpillars, mummy berry, blueberry scorch virus	yes	no

IPM field guide for small-scale berries	E.S. Crop Consult	Developing IPM field guide resource for small-scale berries (will be released in 2021).	yes	no
Jennifer Williams lab, UBC	University of British Columbia, Williams lab	The lab has done several research projects at the Cowichan Garry Oak Preserve (Nature Conservancy of Canada). They have asked research questions about the efficacy of restoration projects (to remove invasive grasses), about pollinator interactions, and about herbivory on Garry oak trees. This latter project is probably about insects that are neither beneficial nor pests (most of the herbivorous insects were native). Currently there is work being done on how changes in rainfall might change the herbivorous arthropod community.	yes	yes
Loopex (Autographa californica polyhedrosis virus) – A new option for organic looper control. Dr. Michelle Franklin	Kwantlen Polytechnic University- Institute for Sustainable Horticulture/ Agriculture and Agri Food Canada		yes	no
Management of soil-borne pests and diseases in raspberry and strawberry: Dr. Eric Gerbrandt, Plant Scientist,	Sky Blue Horticulture Ltd.	This project seeks to improve management tools for soil-borne pests and diseases, especially nematodes and Phytophthora root rot, to increase fruit yield and quality in raspberry and strawberry. ntly being re-evaluated after application of experimental treatments.	yes	no
Monitoring of arthropod pests in raspberry and blueberry germplasm: Dr. Michelle Franklin, Research Scientist,	Agassiz Research and Development Centre, Agriculture and Agri-Food Canada	Providing the breeding program with information on the relative susceptibility or resistance of advanced selections to key arthropod pests to inform decisions about release and management of new cultivars.	yes	no
Non-Chemical Vole Control in Berry Fields: Sofi Hindmarch, Project Coordinator,	Fraser Valley Conservancy	Assessing effectiveness of a non-chemical option for killing voles (i.e., a commercial trap that has a self-resetting, bolt-action kill mechanism) as compared to rodenticides.	yes	no
Non-crop host plants of common Canadian agricultural arthropod pests	Pollinator Partnership Canada	A summary and database of non-crop host plants for common Canadian pest arthropods. The purpose is to help inform plant selection for habitat restoration in agriculture that does not exacerbate pest pressure in crops.	no	no

Paul Abram	Agriculture and Agri-Food Canada	Conducts research on bio-control of invasive species	yes	no
Practices to Protect Pollinators from Pesticides in Highbush Blueberry	Pollinator Partnership Canada	The guide will provide information on importance of pollinators to blueberries, impacts of pesticides, and actions growers and beekeepers can take to protect pollinators	yes	no
Spray technology to improve product efficacy- Low volume sprayers can provide better coverage and can reduce run-off. Dr. Michelle Franklin	Kwantlen Polytechnic University- Institute for Sustainable Horticulture/ Agriculture and Agri Food Canada		yes	no
Stephen Pernal Ph.D.	Agriculture and Agri-Food Canada	Safe and efficacious use of antibiotics for the control of honey bee brood diseases that minimize residue deposition in honey. Improvement of disease management in honey bees. Management of honey bee diseases using lysozyme	no	no
Todd Kabaluk	Agriculture and Agri-Food Canada	bio-pesticide trials on wireworm with producers (Amara Farm) in the Comox Valley	yes	yes
Wim van Herk	Agriculture and Agri-Food Canada	Involved in wireworm studies as well as western corn rootworm studies. In 2020 tested a new wire worm lure on 5 sites across Vancouver Island (Courtenay, Comox, Duncan, Saanich). Lure was successful and can be used for future surveying.	yes	no
Projects, Research Reports, and Fact Sheets				
Agricultural Pest Identification & Management Tools for the Cariboo	BC Agriculture and Food Climate Action Initiative	Set of tools relevant to Cariboo priority pests. 2 webinars (grasshoppers and agricultural weeds). 3 fact sheets: Cariboo – Pests: Agricultural Alert Species for the Cariboo Region (true armyworm, tall yellow buttercup, western corn root worm, phytopthora root rot, quackgrass) Cariboo – Pests: Brown Marmorated Stink Bug Cariboo – Pests: Perennial Pepperweed	yes	no
Contrasting Pollinators and Pollination in Native and Non-Native Regions of Highbush Blueberry Production	Michigan State University and Simon Fraser University, Elle lab	Peer-reviewed research publication on bee communities in blueberry including information from the lower mainland BC. Supplementary material includes bee species data.	yes	no

Evaluation of Thrips Damage to Potatoes in a Changing Climate	BC Agriculture and Food Climate Action Initiative	This project assesses how potato yields are affected by thrips at varying crop stages, local thrips transmission of tomato spotted wilt virus, and the varietal preferences of thrips (all in relation to measured growing season weather conditions). Project include a report and a fact sheet.	yes	no
Flowering phenology and nesting resources influence pollinator community composition in a fragmented ecosystem	Simon Fraser University, Elle lab	Peer-reviewed research publication on bee species composition and habitat associations on Vancouver Island. Not focused on agricultural pollination populations or agricultural questions. Supplementary material includes species lists and habitat associations on Vancouver Island.	yes	yes
Fraser Valley – Agricultural Pest (Activities, Gaps & Priorities) Assessment	BC Agriculture and Food Climate Action Initiative	Summarizes and documents pest surveillance, monitoring and management effort across the Fraser Valley agriculture sector. Includes a final report, a searchable excel file of pest projects in the region, and an inventory of activities, resources and projects (for both crops and livestock)	yes	no
Fraser Valley – Enhancing Information and Collaboration for Managing Emerging Pests	BC Agriculture and Food Climate Action Initiative	This includes an inventory analysis. It identifies two pests (Helminths and Spotted Wing Drosophila) for the focus of two cross-commodity planning sessions. The analysis confirmed seven topics for fact sheets. 7 fact sheets are: Darkling Beetle, Downy Mildew, Spotted wing drosophila, weevils in berry crops, western corn root worm, weevils in nursery and floriculture, important agricultural weeds (lambs quarter, redroot pigweed, tansy ragwort, himilayan blackberry, yellow nutsedge)	yes	no
Pollinator nesting guilds respond differently to urban habitat fragmentation in an oak-savannah ecosystem	Simon Fraser University, Elle lab	Peer-reviewed research publication on bee species composition and habitat associations on Vancouver Island. Not focused on agricultural pollination populations or agricultural questions.	yes	yes
Practices to Reduce Bee Poisoning from Agricultural Pesticides in Canada	Pollinator Partnership Canada and Agriculture and Agri-Food Canada	This guide provides information for farmers, beekeepers, and pesticide applicators on how to reduce bee poisonings from agricultural pesticides. Includes information on both managed and native pollinators, how to read labels, pesticide testing	no	no

		procedures and risk characterization, and a table of AI with mitigation level.		
Priority Pests: Scan, Consultation & Action Plan	BC Agriculture and Food Climate Action Initiative	Cariboo emerging pests scan. A methodology for prioritizing pests in a changing climate based on surveys and climate change mapping and BEC zones. Resulted in a ranking for all problem species. Includes management recommendations and references for each species.	no	no
The pollination ecology of highbush blueberry (Vaccinium corymbosum) in British Columbia	Simon Fraser University, Elle lab	Ph.D. Thesis by Kyle Bobiwash assessing bee populations, pests, and beneficial insects in blueberry in the lower mainland, BC in relation to land characteristics and weather.	yes	no
The reliance on and attraction to pollinators of Canadian crops	Pollinator Partnership Canada and the Pest Management Regulatory Agency	A comprehensive review and summary of the attractiveness to and reliance on pollinators of all crops in Canada. Includes information on attraction to honey, solitary, and bumble bees, mating systems of crops, area in Canada, etc. Additional, in-depth treatment of some crop groups also available.	no	no
Toward a U.S. national program for monitoring native bees (Biological Conservation)	University of California, Riverside	Peer-reviewed policy paper based on a collaborative network of scientists that are working to create a US National native bee monitoring program, led by UC Riverside and the USDA. Can act as a model for others to use for regional, coordinated monitoring programs.	no	no
Vancouver Island Regional Adaptation Strategies (Impact Area #2)	BC Agriculture and Food Climate Action Initiative	A high-level summary of potential climate change effects on pests and pollinators on Vancouver Island based on research and farmer experience in the Impact Area #2 Chapter on Changing Pests and Beneficial Insect Populations	yes	yes
Water into nectar: the effects of seasonal drought on bumble bee and flowering plant communities	University of Victoria, MSc project, Andrew Simon	Investigation of the impacts of seasonal drought on plant phenology and bumble bee community ecology across gradients of disturbance and soil moisture in a semi-arid ecosystem on Galiano Island.	yes	yes

Production Guides and Field Guides

BC Blueberry Council field guide	BC Blueberry Council	Field guide for identification of insect pests, diseases, viruses, abiotic disorders and beneficial insects. Includes numerous helpful photos for ID, but no management information.	yes	no
BC Cranberry Growers' Association	BC Cranberry Growers' Association	Information on cranberry growing in BC including and insect pest identification guide, IPM bulletins, and links to other cranberry growing information.	yes	no
BC Cranberry Insect Pest Identification Guide	BC Cranberry Research Society	Pocket reference guide of pests in cranberry in BC. Short, pictorial guide of common pests in cranberry in BC and summary information on control. The guide notes that more detailed information on pests in the guide along with pest management topics for cranberries is available in the manual: IPM for Cranberries in Western Canada. 26 pages.	yes	no
Berry Production Guide - Beneficial Management Practices for Berry Growers in British Columbia	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations Guides available for blackberries, blueberries, cranberries, currants and gooseberries, raspberries, and strawberries.	yes	no
Best Practices Guide for Grapes for British Columbia Growers	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Checklist of beetles (Coleoptera) of Canada and Alaska			yes	no
Ecoregional Planting Guides for Pollinators	Pollinator Partnership Canada	In-depth guides for land managers, farmers, and gardeners on pollinators, ecoregional characteristics, creating habitat for pollinators, different types of pollinators and life history. Each guide contains a list of pollinator supporting native plants with characteristics. There is a guide for each of the three ecoregions in the Vancouver Island region.	yes	yes

Environmental Farm Plan Reference Guide. Chapter 5- Pest management	Agricultural Research and Development Corporation	This chapter describes how Integrated Pest Management practices contribute to reduce the impact of managing agricultural pests on the environment. It contains introductory information on the relationship between pest management and the environment. It also contains information on environmental concerns, legislation and beneficial management practices related to pest management and pesticides.	yes	no
Farming with Native Beneficial Insects	The Xerces Society	Comprehensive guide on ecological pest control solutions in agriculture with information on the ecology of native beneficial insects and how to increase their numbers, identification, and habitat support.	no	no
Floriculture Production Guide (PDF, 3.4MB)	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Fresh Market Grape Production - Best Practices Guide in British Columbia (2009-2010)	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Hazelnut Production Guide	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Insects and plant diseases: Plant pest and disease management in commercial crops	BC Ministry of Agriculture	Information on how to identify and manage common crop pests and diseases in British Columbia with links for: berries, field vegetables, grains, oilseeds and forage, grapes, greenhouse vegetable and floriculture crops, nursery and ornamentals, nuts, fruit trees. Also, pest alerts and invasive pests available on this site.	yes	no
Integrated Pest Management for Cranberries in Western Canada	Agriculture and Agri-Food Canada	Comprehensive summary of pests, beneficial insects, and IPM in cranberry in BC. Includes pictures, lifecycles, status, detection and monitoring, and management. 44 pages	yes	no
Integrated Pest Management for Turfgrass Managers	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia	yes	no

		published by the B.C. Government and Industry Associations		
Mushroom Production Guide (2008-2009) (PDF, 2.1MB)	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Natural Insect, Weed & Disease control	Linda Gilkeson	Pacific Northwest organic gardener information on how to manage pests, diseases and weeds for vegetable and fruit gardens, lawns, roses and other ornamentals. Companion web pages display the colour versions of over 200 book illustrations plus additional photographs of pest and diseases.	yes	no
Nursery Production Guide (PDF, 6MB)	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Pacific Northwest Pest Management Handbook	A Pacific Northwest Extension Publication (Oregon State University, Washington State University, University of Idaho)	An online guide combining three separate handbooks: PNW Insect Management Handbook, PNW Plant Disease Management Handbook, PNW Weed Management Handbook. Searchable by crop, weed or disease.	yes	no
Pesticides Registered for Ornamental Crops (PDF, 773 KB)	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Planning for Biodiversity a Guide for BC Farmers and Ranchers	BC Ministry of Agriculture	The Biodiversity Guide is designed for farmers and ranchers who wish to increase their understanding of biodiversity and what it means to their operations. It offers ideas on how agricultural producers can manage for biodiversity, and it provides some tools for doing so. The guide can be used in designing, implementing, and monitoring a Biodiversity Management Plan.	yes	no
Pollinators: Protection & Stewardship	Habitat Acquisition Trust	Short, accessible guide on pollinators and how to help for southern Vancouver Island.	yes	yes

Resilient Gardens: Pollinator Gardens, Garlic Diseases, Pest Update	Linda Gilkeson	Information on how to grow gardens for pollinators. Topics include pollination biology and common pollinators, what to plant to feed them (and what not to plant), nest sites for bees and protecting pollinators from insecticides. The second section focuses on identifying and managing garlic root diseases. Updates are included on spotted wing Drosophila, pea leaf weevils and a new disease, downy mildew of basil.	yes	no
Tree Fruit Production Guide	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Vegetable Production Guide - Beneficial Management Practices for Commercial Growers in British Columbia	BC Ministry of Agriculture	Crop production, pest management and best practices guides available in British Columbia published by the B.C. Government and Industry Associations	yes	no
Apps, Websites, Organizations				
Applied Bio-nomics		Pest control consulting and biocontrol insects. Information on the site on pests and control.	yes	yes
BC Decision Aid System	Okanagan Sterile Insect Release Program and Washington State University	This is a decision aid system for Okanagan fruit growers. It uses local weather stations to power a series of decision support tools for fruit production management including recommendations for pest management using conventional or organic practices. It includes model for: codling moth, honeybee foraging, Mullein (Campylomma) bug, oblique-banded leafroller, peach twig borer, San Jose scale, Western cherry fruit fly, apple scab, fire blight	yes	no
Bee-Connected App	Crop Life Canada/ Canadian Honey Council	BeeConnected connects registered beekeepers with registered farmers and contractors, enabling two-way communication on the location of hives and crop protection product activities (spraying). Contractors and farmers are able to input information on their crop protection activities that may be of interest to a beekeeper, and	no	no

		beekeepers are able to notify nearby farmers of the location of their hives.		
Bee-Health App	Government of Alberta	The Bee Health app is based on current scientific knowledge to address honey bee diseases and pests. It is a resource to help beekeepers and other users to detect, diagnose, manage and treat honey bee diseases and pests. It includes pictures and treatment options which aid beekeepers in adopting appropriate pest management practices.	no	no
BugGuide		Online resource used to identify insects	no	no
Canadian Food Inspection Agency, Sidney	Canadian Food Inspection Agency, Sidney	Various research on fruit crops for diagnosis of regulated virus and virus-like diseases in controlled environment and field block settings.	yes	no
Canadian Organic Standards-- Permitted Substances List	Canadian Food Inspection Agency	Permitted substances lists	no	no
Coastal Invasive Species Council	Coastal Invasive Species Committee Society	The website contains technical sheets, programs, and articles regarding invasive species in the Vancouver Island and Sunshine Coast regions.	yes	yes
Dynamic Ecosystem Crop Protection	Dynamic Ecosystem Crop Protection, Bejay Mills	Consultation for many berry, cannabis, and vegetable producers on Vancouver Island and Salt Spring Island on IPM program design, crop protection consulting, and pest scouting. Distribute biological control products and incorporate the use of predators insects and bio-pesticides. Website includes information on pests and control options.	yes	yes
ES Crop Consult	ES Crop Consult Ltd.	Integrated pest management consulting and research company. They provide a number of resources on their website including results of research they have conducted, factsheets with information on common and emerging pests, disease and pest management. Focused primarily on the Fraser Valley. Developing IPM field guide resource for small-scale berries (will be released in 2021).	yes	no
iNaturalist		An app (and website) that acts as a platform for experts and non-experts to input observations on plants and animals. Data is stored and available for use Can be used for presence/absence and for identification both through crowdsourcing and	no	no

		recognition algorithms. Can be used as a resource for data and for research.		
Insight Citizen Science App	Pollinator Partnership Canada	An app that allows users to input data on pollinator abundance and diversity using a standardized data input format. Good for comparing pollinator abundance and diversity among habitats or plant types. Can be used by non-experts. Data are publicly available.	yes	no
Invasive Alien Plant Program (IAPP) Database & Map Display.	Government of BC	The IAPP database contains invasive plant surveys, treatments, and activity plans for the entire province of B.C. The comprehensive data in IAPP is entered by a wide variety of user groups (ministries, regional districts, weed committees, forest licensees, utilities, conservation groups, federal departments and others) on an on-going basis.	no	no
Invasive Species Council of BC	Invasive Species Council of BC	The website contains information on invasive species in BC including lots of resources and links	yes	no
Island Pollinator Initiative	Pollinator Partnership Canada	Website with information on pollinators and pollinator conservation with links to resources on issues, identification, creating habitat, and local Vancouver Island region organizations involved in pollinator conservation. Also has a 10-part pollinator recorded webinar series on pollinators and habitat creation specific to the Vancouver Island region.	yes	yes
Lucidcentral Identification and Diagnostic Tools	Lucid	Online resource used to identify insects	no	no
Pest Management Regulatory Agency, Pollinator Protection webpage	Pest Management Regulatory Agency	Information and links on protecting pollinators in agriculture, the risk assessment framework, and pollinator reports.	no	no
Pesticide Product Label Search	Pest Management Regulatory Agency	Online search tool for pesticide label information. There also is an App available	no	no
Pollinators of British Columbia App and database	Simon Fraser University	The app includes data on pollinators and plant associations in six regions of BC including two in the Vancouver Island region. The app was developed by Laura Melissa Guzman, Tyler Kelly, Melissa Platsko, Leithen M'Gonigle, Lora Morandin and Elizabeth Elle in collaboration with Pollination Partnership Canada and the Native	yes	yes

		Bee Society of British Columbia. The app uses data collected by the Elizabeth Elle lab.		
Royal BC Museum collections	Royal BC Museum	Online, searchable database of RBCM collections. For specific research questions, taxa, and/or regionally filtered data, requests can be made directly to the collections manager.	yes	no
Saanich Native Plants	Saanich Native Plants	Native plant material and consultation for native plant restoration.	yes	yes
UC IPM: Statewide Integrated Pest Management Program	University of California Agriculture & Natural Resources	Comprehensive website with information on agricultural pests and integrated pest management for most crops grown in California. Specific to California but useful for the Vancouver Island region. IPM sites from other universities such as Cornell also are a resource.	no	no
Other Resources				
Fraser Valley IPM newsletters	Industry and Ministry of Agriculture	IPM newsletters are available for Fraser Valley growers for cranberry, blueberry, raspberry and Cole crops. These newsletters are released throughout the growing season, and each newsletter is implemented via a different combination of industry and Ministry of Agriculture partners.	yes	no
Certified Organic Association of BC listserv	Certified Organic Association of BC	This is a forum for organic farmers to post questions, answers and exchange ideas and share information regarding organic production, marketing issues, current issues, events and more. It is widely used by the sector for pest management concerns.	yes	no
Research Priorities 2020	BC Strawberry Growers Association	Each year, the BCSGA releases a list of their priority pests (ranked high, medium and low). This list included weeds, insect pests/arthropods, and viruses/diseases. The list also names specific management practices, or research questions that they are soliciting proposals for, and would like to fund.	yes	no

Research Priorities 2020	Raspberry Industry Development Council	Each year, the RIDC releases a list of their priority pests (ranked high, medium and low). This list included weeds, insect pests/arthropods, and viruses/diseases. The list also names specific management practices, or research questions that they are soliciting proposals for, and would like to fund.	yes	no
Research Priorities 2020	British Columbia Blueberry Council	Each year, the BCBC releases a list of their priority pests (ranked high, medium and low). This list included weeds, insect pests/arthropods, and viruses/diseases. The list also names specific management practices, or research questions that they are soliciting proposals for, and would like to fund.	yes	no
Other Jurisdictions				
Resources				
Canada Horticulture Council Crop Profile Sheets	Government of Canada	Crop Profile sheets for 32 different crops cover grower issues and gaps in pest management, identified through stakeholder consultations are described in each of the three main sections (disease, insect and mite and weed) and under each pest description. A list of provincial specialists and Integrated Pest Management (IPM) resources, are provided at the end of the profile.	no	no
Massachusettes Cranberries website	Cape Cod Cranberry Growers Association	Many resources for members. Grower alerts, frost information (could be a DST) newsletter etc.	no	no
Michigan State University Blueberry Extension	Michigan State University	Mobile IPM scouting guide. Historic newsletters and other resources.	no	no
Small Fruit Update	Misc partners: Washington, Oregon, BC	The SFU is a weekly resource for the Northwest berry industry. It features regional crop reports, industry news, pest management, research and industry events. The SFU is free to all readers, made possible by the dedicated sponsorships from regional fruit commissions and councils across the Northwest and North America.	yes	no
Washington State University Agriculture Extension Pests, Plant Diseases and Weeds Page	Washington State University	Approximately 150 unique resources available for purchase and download pertaining to pests, plant diseases and weeds.	yes	no

Appendix 4: Vancouver Island Region Monitoring Activities

Type	Organism	Program	Organization(s)	Geographic area	Details	Data
Pest	Many	Bonnie's bugs	Bonnie's bugs (private agricultural consulting company)	Comox Valley	Private crop consultant currently monitoring 4 cranberry farms for pests and a carrot crop on one farm. They visit the farms a season to assess pests and advise on control strategies in an IPM framework.	not available
Pest	Gypsy moth	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	CFIA invasive species monitoring programs are run by the Victoria office with all identifications provided by the main laboratory in Ottawa.	not available
Pest	Japanese beetle	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	CFIA invasive species monitoring programs are run by the Victoria office with all identifications provided by the main laboratory in Ottawa.	not available
Pest	Blueberry maggot	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	CFIA invasive species monitoring programs are run by the Victoria office with all identifications provided by the main laboratory in Ottawa.	not available
Pest	Oriental fruit moth	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	CFIA invasive species monitoring programs are run by the Victoria office with all identifications provided by the main laboratory in Ottawa.	not available

Pest	Ambrosia beetles	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	CFIA invasive species monitoring programs are run by the Victoria office with all identifications provided by the main laboratory in Ottawa. Ran a survey for two non-native but well-established ambrosia beetles, Anisandrus dispar and Xyleborinus saxesenii, attacking fruit trees at the Centre for Plant Health in Sidney.	not available
Pest	Golden nematode	CFIA agricultural invasive species monitoring program	Canadian Food Inspection Agency (CFIA)	Vancouver Island	Considered quarantine pests because if left unmanaged they can reduce yields of potatoes and other host crops such as tomatoes and eggplants by up to 80 percent. Have been detected in the past on Vancouver Island. CFIA conducts periodic sampling to monitor.	not available
Pest	Forest invasive species	CFIA forest health program	Canadian Food Inspection Agency (CFIA)	Victoria and surrounding area, mid-Island	Two roaming locations (generally one in Victoria and surrounding area one up-island) on the Island have been surveyed each year since 2012 to monitor for invasive species in a forest setting using funnel traps and various targeted lures. When time permits bi-catch in these traps is also noted for potential invasive species.	not available
Pest	Invasive weeds	Coastal Invasive Species Committee (Coastal ISC)	Coastal Invasive Species Committee (Coastal ISC)	Vancouver Island	Continually survey and, where necessary, treat areas that have invasive weed species. They have treated approximately 1,200 sites over the last 5 years. Data are available on the Invasive Alien Plant Program (IAPP) database which can be searched for both Coastal ISC treatments and weed species.	available

Pest	Many	Dynamic Ecosystems Crop Protection	Dynamic Ecosystems Crop Protection (private agricultural consulting company)	Vancouver Island region	Consultation for many berry, cannabis, and vegetable producers on Vancouver Island and Salt Spring Island. IPM program design, crop protection consulting, and pest scouting. Use a qualitative monitoring method that is customized to the particular operation and crop being monitored. Leaf flips, fruit observations, root zone observations, traps.	not available
Beneficial: pollinators	Pollinators	Garry oak associated pollinator communities	Simon Fraser University, Elle lab	Victoria region and Cowichan	Pollinator collections associated with Garry oak ecosystems. Mainly native bees but also collections and identification of syrphid flies and wasps visiting flowers. Not monitoring *per se* but some of the few systematic collections (pan, aerial netting) of bees and other pollinators, identified to species, in the Vancouver Island region.	available
Pest	Many	Islands Organic Producers Association (IOPA)	Islands Organic Producers Association (IOPA)	Vancouver Island region	For organic certification, operators need to list pests on their farm. They also are required to list any pest products being used or management techniques. Some members have participated in research targeted on specific pests such as wireworm and gypsy moth.	not available
Beneficial: pollinators	Bumble bees	Masters Thesis, Andrew Simon	University of Victoria	Galiano Island	Monitoring and collections of bumble bees in relation to plant communities and climate change covering 2018-2019.	available
All	Many	Metchosin Biodiversity Project	Metchosin Naturalists and University of Victoria	Metchosin	Many bioblitzes with data available. Also flying insect biomass monitoring ongoing and began in 2018. Specimens sorted into major flying insect orders (e.g., flies, bees, wasps and ants). The number of individuals and the biomass for each insect order was recorded.	available
Beneficial: pest control	Bats	North American Bat Monitoring Program (NABat)	BC Ministry of Environment	North America (Launched in BC in 2016)	Program to document bat species around the province. The goals of this program are to detect relative changes in bat population sizes and species' distributions over time.	available

Pest	True armyworm	Plant Health Unit	Ministry of Agriculture	Vancouver Island	Highest populations on central and north island since 2017 outbreak. Monitoring program in place since outbreak. Concerned about when next outbreak will come.	not available
Pest	Western corn rootworm	Plant Health Unit program	Ministry of Agriculture	Vancouver Island	Forage surveys that were initiated due to Army Worm outbreak of 2017 also surveyed for this pest	not available
Pest	Grape phylloxera	Plant Health Unit program	Ministry of Agriculture	Vancouver Island	Grape surveys completed 1 year, 2020 fall. Not sure if GP will spread or get worse. This is an ongoing concern.	not available
Pest	Spotted wind drosophila	Plant Health Unit program	Ministry of Agriculture	Vancouver Island	10 years ago- SWD (2010, 2011, 2012). Surveyed berries and grapes.	not available
Pest	Asian giant hornet	Plant Health Unit program	Ministry of Agriculture	Vancouver Island	Surveyed for this last 2 years by Ministry and partners.	not available
Pest	Strawberry wilt virus (caused from *Verticillium dahliae* fungus)	Plant Health Unit program	Ministry of Agriculture	Lower Mainland and Vancouver Island	A few years ago, sampled 25 farms (some on Vancouver Island)	not available
Pest	Various	Plant Health Unit program	BC Honey Producers Association	Across province, includes Vancouver Island	BCHPA has a hive monitoring study funded by Bee Aware. Monitoring hives across province with continuous data regarding health of the hive.	not available
Pest	Brown Marmorated Stink Bug	Plant Health Unit program	Ministry of Agriculture	Fraser Valley	Monitoring done with Canadian Agricultural Partnership funding. 2019/2020 conducted surveillance for BSMB in hazelnut in the Fraser Valley. Potentially expanding to Vancouver Island in 2021.	not available

Pest	Geese	Regional Goose Management Strategy	Capital Regional District/ Environment Canada	Capital Regional District (CRD)	A long-term strategy to reduce and control geese population in the region.	unknown
Beneficial: pest control	Spiders	Royal BC Museum	Royal BC Museum	British Columbia	Opportunistically collecting spiders around the province. Specific data requests can be made.	available
Beneficial: pollinators	Pollinators	Species at risk	Ministry of Environment	Gulf Islands, Saanich Peninsula	Collections of pollinator species at risk on Gulf Islands and Saanich Peninsula. Mainly butterflies (not agriculturally important pollinators) but also focusing on some native bee species (E.g. *Habropoda*)	available
Pest	Asian Giant Hornet	Trap Monitoring Vancouver Island 2020	Individuals associated with the Nanaimo Beekeepers Association	Vancouver Island	Individual associated with the Nanaimo Beekeepers distributed 60 traps through Nanaimo and Comox beekeeping clubs. The scale and scope of monitoring for AGH in 2021 is not known, but there is a need for this monitoring to continue in a coordinated manner on Vancouver Island in 2021, and this is likely to be led by CFIA.	available

Appendix 5: Species of Concern as Identified by Interviewees

Pest	Scientific name	Currently in VIR	Crops
Animals			
Africanized honey bee	*Apis mellifera x Apis scutellata*	no	honey bees
Ambrosia beetles	*Gnathotrichus sulcatus*	yes	tree fruit
Aphids	Aphidoidea	yes	cole crops
Apple maggot	*Rhagoletis pomonella*	yes	apple, other tree fruits
Asian giant hornet	*Vespa mandarinia*	maybe	honey bees
Asparagus beetle and spotted asparagus beetle	*Crioceris asparagi, Crioceris duodecimpunctata*	yes	asparagus
Blueberry maggot	*Rhagoletis mendax*	no	berries
Brown marmorated stink bug	*Halyomorpha halys*	yes	berries, other
Bruce's spanworm	*Operophtera bruceata*	yes	raspberry
Cabbage worm	*Pieris rapae*	yes	Brassicas
Canada goose	*Branta canadensis*	yes	many
Cannabis aphids	*Phorodon cannabis*	yes	cannabis
Carrot rust fly	*Chamaepsila rosae*	yes	Rosacea
Coddling moth	*Cydia pomonella*	yes	apple, pear
Cranberry tipworm	*Dasineura oxycoccana*	yes	cranberry
Cutworms	Noctuidae	yes	many
Deer mice	*Peromyscus maniculatus*	yes	many
European chafer	*Rhizotrogus majalis*	yes	turf and nearby roots (berries)
Flea beetle	Alticini	yes	many veg crops
Fungus gnat	Mycetophilidae and Sciaridae	yes	cannabis
Golden nematode	*Globodera rostochiensis*	yes	Solanaceae spp.
Grape phylloxera	*Daktulosphaira vitifoliae*	yes	grapes
Greater wax moth	*Galleria mellonella*	no	bees
Japanese beetle	*Popillia japonica*	no	berries
Leaf roller	Tortricidae	yes	berries
Leather jacket bug	*Tipula paludosa*	yes	grass (forage)

Pest	Scientific name	Currently in VIR	Crops
Loopers	*Trichoplusia ni*	yes	
Lygus bug	*Lygus* spp.	yes	strawberry, others
Nematodes			strawberry
Oblique banded leaf roller	*Choristoneura rosaceana*	yes	Rosaceae
Oriental fruit moth	*Grapholita molesta*	no	soft fruit. (cherries or peaches)
Rabbits	Leporidae	yes	many
Rodents	Rodentia	yes	many
Root aphid	Phylloxera	yes	cannabis
Root lesion nematode	*Pratylenchus* spp.	yes	raspberry
Rose stem girdler	*Agrilus cuprescens*	no	caneberries
Slugs	Gastropoda	yes	many
Small hive beetle	*Aethina tumida*	no	bees
Spanworms	Geometridae	yes	small orchard
Spider mite	Tetranychidae	yes	cannabis, many
Spotted lantern fly	*Lycorma delicatula*	no	berries, grapes
Spotted wing drosophila	*Drosophila suzukii*	yes	soft fruits
Strawberry blossom weevil	*Anthonomus rubi*	no	strawberry
Thrips	Thysanoptera	yes	many
Tropilaelaps (mite)	Tropilaelaps spp.	no	bees
True armyworm	*Mythimna unipuncta*	yes	forage: grass, corn, barley, peas, oats
Weevil	Curculionoidea	yes	berries
Western corn rootworm	*Diabrotica virgifera*	no	corn
Western yellowstriped armyworm	*Spodoptera praefica*	no	feeds on broadleaf (alfalfa, buckwheat) corn
Wireworm	Elateridae	yes	many

Diseases/pathogens/fungus			
Anthracnose canker	*Neofabraea malicorticis (Cryptosporiopsis curvispora); Neofabraea alba (Phlyctema vagabunda)*	yes	apple, pear
Apple decline (tender fruit decline)	Complex of diseases and abiotic stress	no	tree fruits
Apple scab	*Venturia inaequalis*	yes	apple
Botrytis	Sclerotiniaceae	yes	cannabis
Cherry X disease, cherry buckskin disease	*Candidatus Phytoplasma pruni*	no	cherry
Eastern filbert blight	*Anisogramma anomala*	no	hazelnuts
False blossom	phytoplasma	no	berries
Grapevine leafroll associated virus	GLRaV	yes	grapes
Little cherry virus	little cherry virus 2 (LChV2), little cherry virus 1 (LChV1), X-disease phytoplasma	no	fruit/ornamental
Phytophthora root	*Phytophthora* spp.	yes	raspberry
Powdery mildew	Erysiphales	yes	fruits, cannabis
Ripe rot	*Colletotrichum acutatum*	yes	berries
Rust	Pucciniales	yes	many
Snot brood	Virus	yes	bees
Verticillium wilt	*Verticillium* spp.	yes	strawberry, stone fruits
Viruses	Many	yes	bees
Weeds			
Barnyard grass	*Echinochloa crusgalli*	Yes	corn
Burdock	*Arctium minus*	yes	raspberry
Buttercup	*Ranunculus repens*	yes	blueberry
Canada thistle	*Cirsium arvense*	yes	
Canary grass	*Phalaris canariensis*	yes	
Chickweed	*Cerastium* spp.	yes	
Crab grass	*Digitaria* spp.	yes	
Creeping yellow cress	*Rorippa sylvestris*	yes	raspberry
Curly dock	*Rumex crispus*	yes	raspberry
Dandelion	*Taraxacum* spp.	yes	
Daphne	*Daphne laureola*	yes	
English holly	*Ilex aquifolium*	yes	
Foxtail barley	*Hordeum jubatum*	yes	
Giant hogweed	*Heracleum mantegazzianum*	yes	
Himalayan blackberry	*Rubus armeniacus*	yes	
Horsetail	*Equisetum arvense*	yes	

Japanese knotweed	*Fallopia japonica*	yes	
Lambs quarters	*Chenopodium album*	yes	
Milk thistle	*Silybum marianum*	yes	
Morning glory	*Convolvulus arvensis*	yes	blueberry
Nightshades	Solanaceae	yes	horticultural crops
Palmer amaranth	*Amaranthus palmeri*	no	forage
Pigweed	*Amaranthus retroflexus*	yes	
Poison hemlock	*Conium maculatum*	yes	
Purslane	*Portulaca oleracea*	yes	
Russian thistle	Salsola tragus	yes	horticultural crops
Scotch broom	*Cytisus scoparius*	yes	forage
Sheep sorrel	*Rumex acetosella*	yes	
Smartweed	*Persicaria* spp.	yes	
Spear grass	Many	yes	
Wild buckwheat	*Polygonum convolvulus*	yes	blueberry
Wild proso millet	*Panicum miliaceum*	yes	corn
Wire grass	Poacea	yes	forage
Yellow nut sedge	*Cyperus esculentus*	yes	berries