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Economic Benefits of Using Sterile Insect Technique and Mating Disruption to Control Codling Moth

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Abstract

In the Okanagan/Similkameen region, the tree fruit industry value chain forms a significant part of the Agricultural Products Cluster. In 2011, 8677 acres of apples comprised 38% of the total horticulture land base. The remaining acreage was planted primarily to sweet cherries (3500 acres) and wine grapes (8100 acres). However, the tree fruit industry value chain is undergoing significant transformational change as the apple acreage has declined from 13 430 acres in 2001, a loss of 4753 acres. This change in the primary production base has had profound processing and marketing implications for the apple sector, and for the government programs such as the Okanagan Kootenay Sterile Insect Release Program (OKSIR) that provide services to the sector.

A social benefit-cost analysis (B/C) was used to evaluate the OKSIR. This analysis measures both the benefits, in the form of cost savings and Sterile Insect Release services that accrue to the commercial apple and pear producers, and the benefits that non-agricultural residents receive, the consumer surplus. The study compares the Benefit/Cost ratios for both the existing Sterile Insect Technique (SIT) to control Codling moth and the use of a mating disruption (MD) technique. The net benefit for MD ($281.47/acre) is higher than for SIT ($258.65/acre). This is also reflected in the higher NPV for MD.

The break-even point for SIT is 6238 acres and 1264 acres for MD. The lower acreage requirement for MD reflects the lower costs associated with MD, and supports the idea that MD is a viable method for controlling Codling moth in areas with relatively small acreages.

Keywords: apples, benefit-cost analysis, contingent valuation, consumer surplus, mating disruption, producer surplus, sterile insect technique, willingness to pay

1. Introduction

Since 1992, the Okanagan Kootenay Sterile Insect Release Program (OKSIR), has been providing an Area-Wide Integrated Pest Management (AW-IPM) service to agricultural producers in the Regional District of the Okanagan Similkameen (RDOS), Regional District of the Central Okanagan (RDCO), Regional District of the North Okanagan (RDNO), and the Columbia Shuswap Regional District (CSRD) (see Figure 1). The role of the Sterile Insect Technique (SIT) as an effective component of sustainable AW-IPM is well understood (Vreysen, Hendrichs, & Enkerlin, 2006). The focus of the OKSIR program is to control Codling moth, *Cydia pomonella,* in apple and pear crops. Codling moth is a serious insect pest of apples, pears, and English walnuts (Note 1). Failure to control Codling moth can result is significant economic damage to the tree fruit industry in these regions.

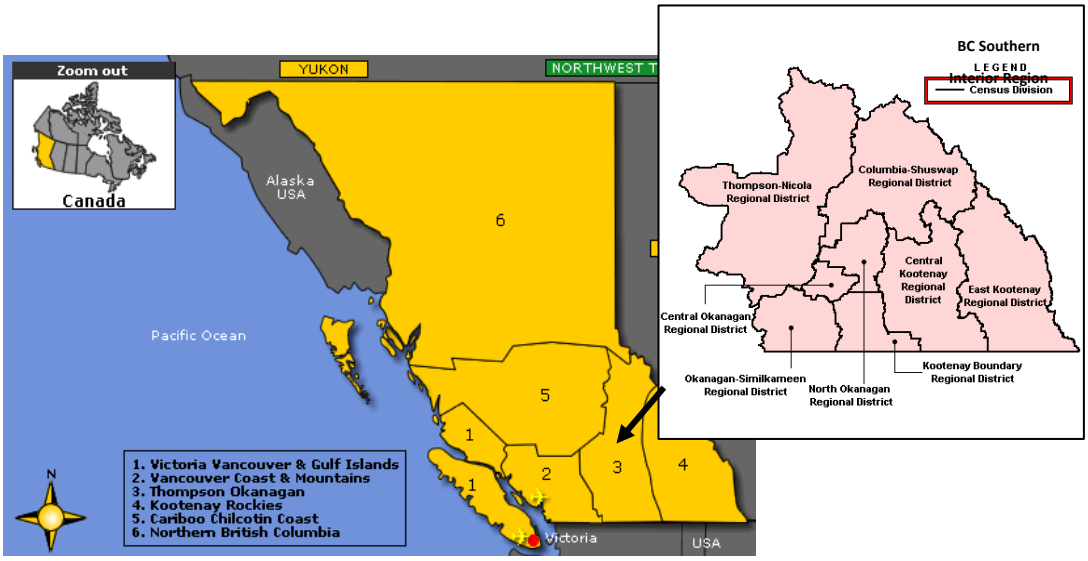

Figure 1. Sterile insect release program area

AW-IPM in the Okanagan employs SIT in the south Okanagan and multi-lure (codling moth/leaf roller) mating disruption (MD) in the central and north Okanagan. The application of both MD and SIT in the Okanagan AW-IPM program provides an opportunity to compare the economic benefits and costs of each approach.

1.1 Background to the Study

In the Okanagan/Similkameen region, the tree fruit industry value chain is a major part of the Agricultural Products Industry Cluster. There is strong evidence to support the proposition that industry clusters are major drivers of rural regional development (Irshad, 2009). When firms cluster, innovation and productivity are enhanced, this in turn improves industry competitiveness (Arikan, 2009; Porter, 2003). In the Okanagan region, the 'Agricultural Products' industry cluster makes a significant contribution to the region's economy. Data developed by Cartier (2013) shows that this cluster outperforms the region in terms of GDP growth, employment growth, and new firm creation. But the structure of the industry cluster is changing, and so too, the government services, such as the OKSIR, provided to the cluster change as well.

In the Okanagan/Similkameen region, approximately 23 000 acres of land is used for tree fruit and grape production. An analysis of Census of Agriculture data from 2001, 2006, and 2011 (Note 2) show a significant decline in the apple acreage from 13 430 acres in 2001 to 8677 acres in 2011 (Table 1). Much of this apple acreage was replaced with sweet cherries which increased from 1930 to 3532 acres, and wine grapes which increased from 6532 to 8136 acres. This change in the primary production base has had profound implications for the processing and distribution segments of the value chain, and the services provided by government agencies. The loss of 4753 acres of apple production has resulted in major consolidation of the apple processing and packaging capacity, where many processing plants were either closed or retooled.

Table 1. Changes in tree fruit and grape acreage

	Acres			CAGR
	2011	2006	2001	
Apples	8677	10 005	13 430	-4.3%
Pears	479	602	753	-4.4%
Plums	314	323	311	0.1%
Cherries (sweet)	3532	2515	1930	6.2%
Cherries (sour)	75	147	254	-11.5%
Peaches	1209	1387	1357	-1.1%
Apricots	216	320	433	-6.7%
Grapes	8136	7012	6532	2.2%
Total	22 638	22 311	25 000	

The implications of this industry transformation for the OKSIR are significant. The cost of the Sterile Insect Release (SIR) program is shared by the commercial apple and pear producers (60%) and the non-agricultural residents (40%) through a property tax levy. As the apple acreage has decreased, the fixed cost of delivering the SIR program to apple and pear growers, on a per acre basis, has risen. As the cost per acre rises, stakeholders begin to question the economic efficiency of the program. That is: is the cost of delivering the SIT program greater than the benefits derived from the program? Related to this question are a number of issues:

- Alternatives to SIT, such as Mating Disruption, are available. Are there more efficient ways to control Codling moth other than SIT? What are the options for best utilization of the SIT facility?
- Tax revenue to support the program has decreased as the apple acreage required to support the program has decreased.
- Some municipalities have residential host trees with only a few to no commercial apple plantings and question whether they should continue to contribute tax revenues to a program from which their rate payers may receive little or no direct benefit.

As the Agricultural Products cluster continues to evolve, new factors have emerged that are beginning to influence the future of the cluster and the OKSIR program's contribution to the cluster. A new pest, the Spotted wing drosophila (SWD), *Drosophila suzukii*, has now invaded the Okanagan/Similkameen regions. SWD is capable of causing considerable damage to the region's cherry producers and the organic fruit sector. Can SIT be used to control this most damaging pest? Regional government, through an effective AW-IPM program, can continue to play a vital role by supporting the changing nature of the cluster.

1.2 Research Problem and Objectives

The purpose of this research is to measure the benefits and costs of the existing AW-IPM program. The research question guiding this investigation is "Are the benefits of the SIR program, to control Codling moth, greater than the cost of delivering the program?" The four research objectives developed to answer this question are listed below.

1) What are the economic benefits of the SIR program for the commercial tree fruit producers located in the four regional districts?

2) What are the economic benefits of the SIR program services for non-agricultural residents of the four regional district areas?

3) What are the costs of delivering the SIR program to the four regional district areas?

4) What is the most efficient method of controlling codling moth populations in the four regional districts?

2. Methodology

A social benefit-cost analysis is used to measure the effectiveness of the SIR program. Benefit-cost analysis (B/C) is drawn from economics and is a technique for comparing alternative investment opportunities; for government, B/C analysis is used to prioritize project funding. B/C analysis has also been used to measure the effectiveness of SIT in other regions of the world. Anaman, Atzeni, Mayer and Stuart (1993) used B/C analysis to measure the effectiveness of using SIT to eradicate the Screwworm fly in Australia, and B/C analysis was used by the International Atomic Energy Agency to evaluate three control options for the Mediterranean fruit fly (IAEA, 1995).

This study compares the Benefit/Cost ratios for both SIT to control Codling moth and the use of a mating disruption technique.

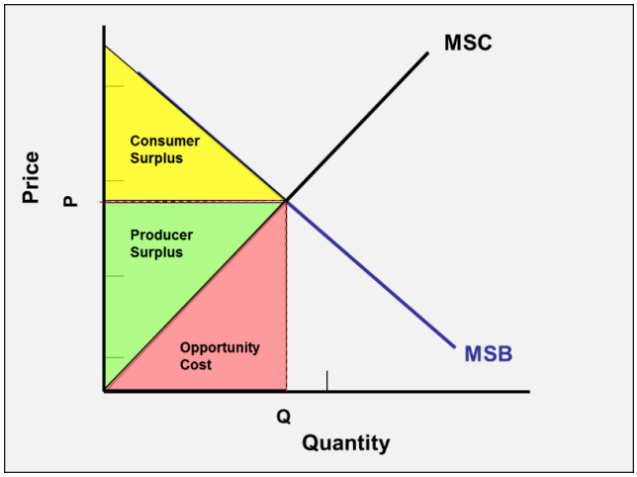

Figure 2. Consumer and producer surplus

Two types of economic benefits are measured, as illustrated in Figure 2. First, the producer surplus (green shaded area), in the form of cost savings and AW-IPM services, that accrue to the commercial tree fruit producers, and second, the consumer surplus (yellow shaded area): the benefits that accrue to the non-agricultural residents. The social benefit is the sum of the producer and consumer surplus. The opportunity cost (purple shaded area) in Figure 2 is the cost to deliver the SIR services. MSC is the Marginal Social Cost curve and MSB is the Marginal Social Benefit curve.

2.1 Benefit to Commercial Tree Fruit Producers

Three producer benefits were identified for commercial apple and pear producers:

1) Savings in the cost of pest control chemicals that would otherwise be used to control Codling moth and the cost associated with the application of these pesticides. The chemical cost was provided by Grower's Supply Limited, and is based on the standard pesticide protocol for Codling moth prescribed by the BC Ministry of Agriculture. The application cost includes the machine cost developed from agricultural engineering tables, fuel, and operator cost.

2) Savings in the cost associated with monitoring Codling moth levels in their orchards. The monitoring cost saving is based on the cost/acre of hiring a crop management consultant to monitor Codling moth levels.

3) Revenue loss due to pre-harvest Codling moth injury associated with pesticide control. The injury reduction benefit is calculated by converting the pre-harvest injury levels into revenue loss per acre. The apple price used for the revenue calculation is the five year average price developed from apple pool closing reports provided by BC Tree Fruit Cooperative.

2.2 Benefit to Non-Agricultural Residents

The consumer surplus is the value to the consumer above the price they pay for a product, and arises from both the direct benefits to residents and the external benefits from the positive externalities associated with the SIR Program. Externalities are an important concept in economics, as their presence can lead to inefficient market outcomes. Externalities are unintended third party consequences that arise from transactions between a buyer and a seller. There are both negative externalities, such as the costs to society that result from pollution, and positive externalities, such as the benefits to society that are derived from research and education. A number of benefits have been identified for this study:

- An increase in the supply of pesticide reduced apples and pears. This can also result in market gains due to meeting higher quality standards for 'low-pesticide level products' (IAEA, 1995).
- Cash savings for residents that no longer have to use expensive pesticide sprays (deBiasio, 1988), or hire commercial pesticide services to spray their home apple (including ornamental crab apple) and pear trees.
- Improved health due to a reduction in the amount of pesticides in the environment, and from the handling of these pesticides (deBiasio, 1988). Also, pesticide use to protect agricultural crops has caused insecticide resistance to develop in insect vectors of disease, such as mosquitos. For example, this has been an important factor in the resurgence of malaria (Klassen, 2005).

- Protection of household pets, livestock, wildlife, and beneficial insects, such as honey bees, that might otherwise be harmed by the use of pesticides (deBiasio, 1988).
- A reduction of pesticide spray drift onto neighboring residential properties (Klassen, 2005).

These were grouped into three main benefits: reduced use of pesticides on their residential property, the reduced use of pesticides by farmers, and reduced pesticide residue in food.

The consumer surplus is measured using the Contingent Valuation, or willingness to pay (WTP) method. WTP is a fundamental tool of applied welfare economics and measures an individual's willingness to pay for a good or service. It is the highest price that a person would pay to have use of the product rather than go without it. WTP differs from 'market price' which is the price at which goods are exchanged in competitive markets. The WTP technique is often used to measure the social benefit associated with public goods, such as medical programs (Olsen & Donaldson, 1998; Donaldson, 1990; Garming & Waibel, 2006), and to control Asian Tiger Mosquito in New Jersey (Halasa et al., 2012).

2.3 SIR Program Cost

The SIR program costs are the relevant operating and administration costs associated with the program, and were provided by the Regional District of the Central Okanagan (RDCO).

Analysis of secondary data provided by the OKSIR program staff was used to measure the operating and administration costs of delivering the SIR program to commercial producers and regional district residents. Secondary data was also used to measure the direct economic benefits for the commercial apple and pear producers. Primary data was collected to measure the program benefits for the non-agricultural residents of the four regional districts. Primary data was collected through the use of survey questionnaires.

2.4 Sample Design and Primary Data Collection

There are two populations associated with this study. The first population is comprised of the commercial apple and pear producers who are directly impacted by codling moth damage. The second population is comprised of the non-agricultural residential property owners that live in the four regional districts: RDOS, RDCO, RDNO, and CSRD. Primary data was only collected from the non-agricultural producers.

Through a combination of internet surveys and print surveys of the non-agricultural property owners, a total of 572 survey responses were received, with property owners representing 90.3% of respondents.

3. Results and Discussion

This study compares the use of SIT and MD in controlling Codling moth populations in the four Regional Districts (the 'region'). A Benefit/Cost (B/C) ratio is calculated for each method of control. The method with the highest B/C ratio is considered to be the most efficient method.

3.1 Economic Benefits of the SIR Program for Commercial Tree Fruit Producers

Three producer benefits are identified: savings in pesticide costs; savings in the cost associated with each orchardist monitoring Codling moth levels in their orchard; and revenue loss due to pre-harvest Codling moth injury associated with pesticide control. The producer benefits per acre for the year 2014 are provided in Table 2.

Table 2. Producer benefit composition per acre - 2014

	SIT		**MD**	
Pesticde cost saving	166.61	42%	166.61	44%
Monitoring cost saving	80.00	20%	80.00	21%
Injury reduction	148.39	38%	130.69	35%
	395.00	100%	377.30	100%

3.2 Codling Moth Injury Reduction

The pre-harvest injury for pesticide control, SIT, and MD are provided in Figure 3. The injury level of 3.1% associated with pesticide control is taken from the work of McGhee, Epstein, and Gut (2011) in Michigan. Their four year study compared Codling moth injury levels in orchard blocks using conventional pesticide control to blocks using MD. This 3.1% injury level is consistent with injury levels measured in Creston, BC (Note 3). In 2013, injury levels for pesticide managed blocks was 3.57%, compared to 62% for abandoned orchards, and 34% for organic producers.

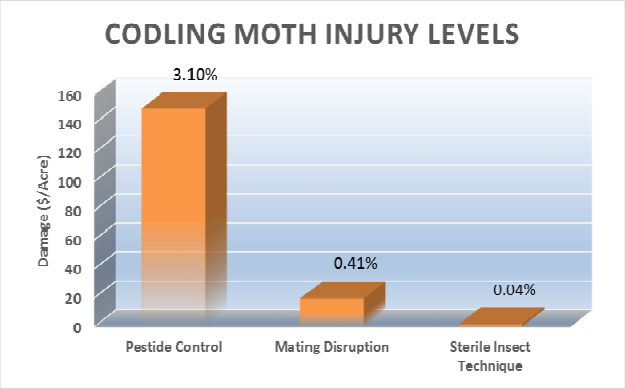

Figure 3. Codling moth injury levels

Injury levels for SIT control and MD control are taken from the report prepared by Paramjit Gill (2014). This study showed that there is a statistically significant difference in the injury levels in SIT blocks (0.04%) compared to MD blocks (0.41%).

3.3 Economic Benefits of the SIR Program Services for Non-Agricultural Residents

This section examines two aspects of economic benefits for non-agricultural residents: the perceived benefit associated with reduced pesticide use, and the willingness to pay for these benefits.

3.3.1 Pesticide Use

Residents were asked to rank their preferences regarding three aspects of pesticide use in the region:

1) The use of pesticides on their property.
2) The use of pesticides by farmers.
3) Pesticide residue in food.

For each aspect they were asked to rank their attitude towards the use of pesticides on a scale of 1–5, where 1=strongly disagree and 5 = strongly agree. The results are provided in Figure 4.

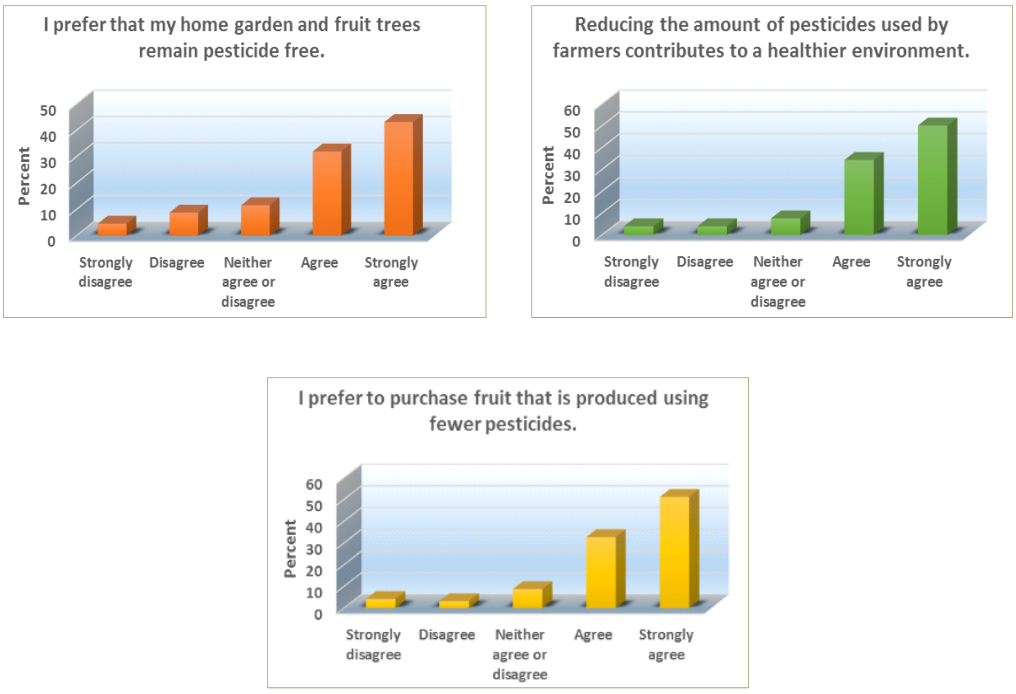

Figure 4. Preference for reduced pesticide use

The data indicate that there is strong preference to reduce the amount of pesticides that are used in the region, both on their own property, and by commercial producers. The data also show a strong preference for purchasing fruit that is produced using fewer pesticides. The mean score, on a scale of 1–5, for each aspect is shown in Table 3.

Table 3. Pesticide reduction scores

Use of Pesticides	Mean Score (Scale of 1–5)	Standard Deviation
I prefer that my home garden and fruit trees remain pesticide free.	4.02	1.154
Reducing the amount of pesticides used by farmers and pest control companies contributes to a healthier environment for my family.	4.24	1.024
I prefer to purchase fruit that is produced using fewer pesticides.	4.25	1.023

A One Way Analysis of Variance (ANOVA) was conducted to identify any differences in the attitudes toward pesticide use between residents of the four Regional Districts. The results of the ANOVA are found in Appendix A. There is a statistically significant difference at the $P < .05$ level in residents' tolerance for the use of pesticides between the four Regional Districts. Post-hoc comparisons using the Tukey HSD test indicated that residents' tolerance for pesticide use in the Central Okanagan is significantly higher than for residents in the other three Regional Districts.

Respondents were grouped into three age groups: ≤ 40 years, 41 to 66 Years, > 67 years. There is no significant difference between the age groups and their attitudes regarding the use of pesticides.

3.3.2 Willingness to Pay

Willingness to pay is the highest price that a person would pay to have the use of a service rather than go without it. For the SIR program, it is a measure of the value to them, of living in a community that uses less pesticide. Essentially the study acts as a referendum on the use of SIR and MD in the region; respondents were asked if they were prepared to support the SIR program, and if so, to choose one of five property tax amounts. These are provided in Table 4. The table converts the amount of tax they are willing to pay into value by multiplying the tax levy/$1000 for to each amount of property tax ($6.00 = $0.0319/$1000 assessed value) by the total residential land value for the region ($30.0 billion). This value is then reduced by excluding the 9.7% of property owners that are unwilling to support the SIR program.

Table 4. Land value tax levy rates

Annual Property Tax	Value
$6.00	$864 164
$8.00	$1 154 024
$10.00	$1 441 176
$12.00	$1 728 327
$14.00	$2 018 188

The maximum amount of tax that property owners are willing to pay is provided in Figure 5. The data shows that 70% of these are willing to pay $10.00 or more per property. The 45 non-property owners also replied to the willingness to pay question. Although they were excluded from the willingness to pay calculations, their intention to pay if they were property owners, is an indication of the value of the program to non-property owners. There was no significant difference in the mean willingness to pay between property and non-property owners.

The consumer surplus is the total amount of tax that property owners are willing to pay to support the SIR program. The consumer surplus, as calculated from the data in Table 4 and Figure 5, is $1 543 505, or $182.88/acre.

It does not matter to residents whether SIT or MD is the method used to control Codling moth. That is, the value

of the SIR program to them is independent of the control method. The consumer surplus, therefore, is the same for both SIT and MD.

Figure 5. Property owners willingness to pay

3.4 Unwillingness to Pay

Of the property owners, 10% said they did not want to support the SIR. They were asked to comment as to why they were unwilling to support the program. Their comments were then organized into six themes as presented in Table 5.

Table 5. Why I don't want to support the SIR program

	Percent
Don't Believe the Program is Working	37.1
Orchardists Should Support The Program Themselves	17.1
Do Not Want to Pay More Taxes	14.3
Not Relevant to Resident	11.4
General Protest Vote	11.4
Not Enough Information to Make Informed Decision	8.6

3.5 Cost of Delivering the SIR Program

The cost to provide SIT or MD to 8440 acres in 2014 is $2.7 million and $2.3 million respectively, or $319/acre and $279/acre. The cost structure for both SIT and MD is provided in Figure 6.

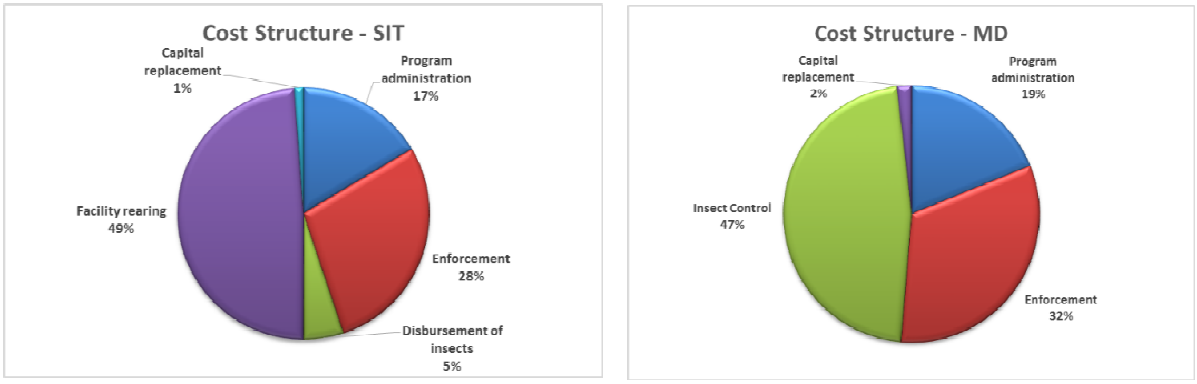

Figure 6. Cost structure for the SIT or MD methods

SIT is more costly to deliver. This is due to the SIT rearing and disbursement costs of $1.4 million compared to $1.1 million for MD supplies and services. The administration cost of $443 348, and enforcement cost of $764

258, are the same for both SIT and MD. The ongoing capital replacement costs are $32 000 annually for SIT and $42 000 annually for MD.

In addition to the ongoing annual operating and capital replacement costs there is a non-recurring cost of replacing the gamma cell at the rearing facility. If SIT were applied to all 8440 acres, the gamma cell would be replaced in 2016 and is expected to cost $1.3 million.

3.6 Comparison of Sterile Insect Technique to Mating Disruption for Controlling Codling Moth Populations

The B/C ratio is calculated as the Present Value (PV) of the cash flows associated with the benefits divided by the PV of the cash flows associated with the costs. The discount period selected for the PV calculations is 30 years. The discount rate is 8%, as recommended by the Treasury Board of Canada for evaluating public projects (Note 4).

The results of the B/C analysis are provided in Table 6. For each control method, SIT and MD, the producer benefit/cost ratio is reported separate from the total B/C ratio. The total B/C ratio is the sum of the benefits for producers (producer surplus), and the benefits for residential property owners (consumer surplus).

Table 6. Benefit/cost analysis summary

	Producer B/C	Total B/C	NPV
Sterile Insect Technique	1.19	1.75	25 350 446
Mating Disruption	1.35	2.01	28 884 527

For both SIT and MD, the B/C ratio is greater than 1.0. This means that the benefits are greater than the costs, and therefore both methods are more efficient than the use of pesticides to control Codling moth. Mating disruption has the highest B/C ratio, primarily due to the lower costs associated with MD, indicating that it the more efficient way to control Codling moth in the region.

The minimum number of acres required to have the producer B/C ratio = 1.0 is considered to be the break-even point; below this acreage minimum the costs are greater than the benefits. The break-even point for SIT is 6238 acres and 1264 acres for MD. The lower acreage requirement for MD reflects the lower costs associated with MD, and supports the idea that MD is a viable method for controlling Codling moth in areas with relatively small acreages.

Another important consideration is whether SIT and MD are substitutes for each other. If this is the case, then it could be argued that SIT in the region should be abandoned in favor of the more efficient MD method. Entomologists attending the recent SIT research sessions (Note 5) believe that SIT and MD are compliments of each other rather than substitutes, and can be combined in some cases to provide more effective control than either SIT or MD alone.

Finally, Table 6 provides the Net Present Values (NPV) for each method. NPV is calculated as PV benefits – PV costs. The NPV calculations show that the benefits to both the producers and the residents far exceed the cost of maintain the SIR program.

3.7 Benefits and Costs per Acre

The benefits, costs, and net benefits per acre for the year 2014 are provided in Table 7. The higher producer benefit for SIT reflects the lower Codling moth injury levels associated with SIT. The willingness to pay of $182.67 is the same for both methods. The willingness to pay value is the total from the survey results. The total benefit per acre for SIT and MD is $577.67 and $559.97 respectively. The cost per acre to provide SIT is higher than for MD, $319.02 and $278.51 respectively. This is due to the rearing costs associated with producing sterile males. Due to the higher cost of delivering SIT, the net benefit for SIT ($258.65/acre), is lower than for MD ($281.47/acre). This is also reflected in the lower NPV for SIT.

Table 7. Net benefits per acre - 2014

	SIT	MD
Producer benefit	395.00	377.30
Willingness to pay	182.67	182.67
Total benefit	577.67	559.97
Cost	319.02	278.51
Net benefit	258.65	281.47

4. Conclusions

This study investigates the value of the AW-IPM program to control Codling moth, in the four Regional Districts that comprise the Okanagan/Similkameen region, using a Benefit-Cost approach. This analysis measures both the benefits that accrue to the farmers (the producer surplus) and the benefits that non-agricultural residents receive (the consumer surplus). The results indicate that the social benefits are greater than the cost to provide the AW-IPM program.

There is a significant benefit for regional apple and pear growers; the producer surplus for SIT and MD, at $395/acre and $377 respectively, is greater than the cost of $319/acre. The study also compared the producer B/C ratios for both SIT and MD to control Codling moth. MD has a higher B/C ratio than SIT, due to the lower cost per acre of providing MD services; however, SIT and MD are considered to be complimentary tools for an Area-wide Integrated Pest Management program. SIT delivers higher producer benefits, but MD requires fewer acres to break-even than does SIT, and can be used in areas that are too small to sustain a SIT program.

The benefits to residents of the four Regional Districts are derived primarily from the reduction in the use of pesticides to control Codling moth. Moreover, 90% of residents clearly value living in a community that uses fewer pesticides; they are willing to pay $0.8 - $2.0 million annually to enjoy these benefits, with a resulting consumer surplus of $1.5 million. The consumer surplus is the same for both SIT and MD as residents enjoy the same benefit regardless of which control method is used. In other words, the externality is the same for SIT and MD.

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Notes

Note 1. University of California Agriculture & Natural Resources. Retrieved from http://www.ipm.ucdavis.edu/PMG/PESTNOTES/pn7412.html

Note 2. Source: Statistics Canada. Retrieved from http://www.statcan.gc.ca/ca-ra2011/

Note 3. Year To Date Summary of Codling Moth Captures, Creston Valley, 2013.Data Collected by Duane Holder

Note 4. Treasury Board of Canada Secretariat (2007). Canadian Cost-Benefit Analysis Guide: Regulatory Proposals.

Note 5. Final FAO/IAEA Research Co-ordination Meeting on 'Increasing the Efficiency of Lepidoptera SIT by Enhanced Quality Control'. June 2-6, 2014.

Appendix

Appendix A. Attitudes to the use of pesticides

Strategic Focus	ANOVA	Okanagan/Similkameen	Central Okanagan	North Okanagan	Columbia/Shuswap
Pesticide use on their property	F(3,561)=5.87, p=.001	M=4.12, SD=1.13	M=3.76, SD=1.24	M=4.27, SD=0.97	M=4.10, SD=1.16
Pesticide use by farms	F(3,562)=3.73, p=.011	M=4.31, SD=1.00	M=4.06, SD=1.12	M=4.39, SD=0.87	M=4.50, SD=0.53
Pesticide residue in food	F(3,562)=3.60, p=.014	M=4.29, SD=1.04	M=4.10, SD=1.13	M=4.10, SD=0.74	M=4.25, SD=1.03