Agriculture in the Alaksen National Wildlife Area

Baseline Assessment Report

Report Prepared by:

Grace Augustinowicz, Kwantlen Polytechnic University/University of British Columbia

Dr. Kent Mullinix, Institute for Sustainable Food Systems, Kwantlen Polytechnic University

Dr. Sean Smukler, Faculty of Land and Food Systems, University of British Columbia

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Executive Summary

Agricultural management practices within the Alaksen National Wildlife Area (Alaksen) have played an important role in maintaining wildlife habitat, and conciliating human activity with the needs of wildlife populations. This study was commissioned by the Canadian Wildlife Services (CWS) to better understand the relationship between farming activities and wildlife habitat provision within Alaksen, and potential options to improve farming and ecological outcomes. This baseline assessment included an extensive literature review, interviews with farmers, and a preliminary analysis of bird surveys. The specific objectives were to:

1. Review and document the current agronomic practices within Alaksen.
2. Conduct a preliminary assessment of how these practices might be impacting habitat and associated wildlife, and identify which practices are most likely to realize multiple ecological objectives of the protected area.
3. Provide recommendations for research to support the development of an agricultural management plan to enhance ecological integrity and services at Alaksen.

Our documentation of the basic characteristics of the farming operations, and approaches for farm management show that farmers in the region are growing a few types of vegetables and grazing cattle in a rotation. Following vegetable production farmers generally try to establish a cover crop in the wintertime. Through this preliminary assessment of current agronomic practices and site conditions we identified a number of challenges to, and opportunities for, realizing multiple ecological and agronomic objectives of the protected area.

One of the primary challenges we identified was posed by the current selection of summer crops that contribute to the late planting of winter cover crops. Late planting is resulting in poor cover crop establishment and potentially a negative feedback loop that could impact both wildlife and agricultural operations. Without time to develop a vigorous cover crop before the waterfowl arrive in the winter, the cover crops are quickly consumed and leave the soil bare and susceptible to erosion, ponding and compaction by birds trafficking the fields. This in turn impacts the farmer's capacity to maintain soil organic matter (SOM) which has important implications for soil quality, and field water dynamics, particularly poor drainage. Farmers at Alaksen report that poor drainage has contributed to the surface accumulation of salts from summertime irrigation, and saltwater intrusion from high water tables. The accumulation of salts in the soil threatens the productivity for all cropping and further exacerbates the negative feedback loop leading to the depletion of SOM. Clearly this negative feedback loop impacts both the sustainability of farm operations and wildlife habitat.

Our preliminary analysis of survey data collected by CWS show some relationship between farm management and patterns in the abundance and distribution of migratory and overwintering bird populations. Crop rotation and field size were found to be potential predictors of bird abundance but a more detailed analysis would be required to understand how farm management specifically is impacting bird field utilization. While we identified that several pesticides used in Alaksen have high levels of ecological toxicity, it is unclear what impacts these pesticides and other contaminants are having on wildlife or ecological function. Based on interviews however, pest pressure and occurrence at Alaksen seems to be significantly lower than in other farms in the area, due potentially to the incorporation of the crop rotations and the inclusion of hedgerows and grass margins around the fields which provide important refuge for a host of beneficial arthropods that help to keep arthropod pest populations under control.

Farmers also reported that over the last decades, their operations have been experiencing a decrease in the quantity and the quality of yields due to excessively wet field conditions extending into the late spring. Following this line of thought, they have expressed increased desire to build economic resilience into their operations by introducing novel crops into their existing rotations.

While our assessment documented an important example of how wildlife and agriculture can be co-managed in a way that has the potential to be mutually beneficial, there are clear indications that this co-management could be improved. A better understanding of the system and its components could be utilized as the framework for the creation and implementation of a management plan that incorporates projected changes in land use and climate, to meet the multiple objectives of the wildlife area over the long-term.

Research Recommendations

Based on our findings we developed a set of recommendations for areas of future research that would likely enhance the development of an effective management plan.

- The current winter cover crop selection and planting practices need to be evaluated to determine their rate of establishment, and their role in maintaining soil quality and supporting wildlife and wildlife habitat. Based on this analysis, alternative cover crop strategies, perhaps using new species or cultivars could be explored.
- A detailed analysis of how the current farm attributes and farming practices may be affecting bird populations could be used to further enhance habitat conditions.
- A detailed examination of how current integrated pest management practices may be affecting the distribution and abundance of pest populations and beneficial arthropod populations is needed to predict potential pest prevalence and abundance, and improve ecological services.
- An evaluation of the short and long-term effects of pesticides and other contaminants on wildlife and wildlife habitat is required to develop a science-based approach to reduce potential impacts.
- An analysis of soil quality across Alaksen agricultural fields is needed to better understand the direction and magnitude of change and enable identification of practices that are most likely to sustain both farm productivity and the provision of food and habitat for wildlife populations.

- An evaluation of the drainage infrastructure and options for improving it is needed to effectively address drainage and salinity issues which are clearly threatening the sustainability of agricultural production within Alaksen.
- An agronomic and economic evaluation of potential shorter season marketable crops that could be integrated into the current crop rotation, could help with the establishment of cover crops at the end of August.
- Much of the recommended analysis above would be substantially enhanced by improved data collection and record keeping of agricultural practices and farmscape management methods.

1. Introduction

Alaksen National Wildlife Area is a protected wildlife area in Delta, British Columbia, Canada. Farming at Alaksen is a central component of its management plan, that is strongly focused on the provision of habitat and food for wildlife. The area encompasses a number of habitat types, and supports and protects a broad range of biodiversity, including some listed as endangered or species at risk, such as the western painted turtle (*Chrysemys picta*), the sandhill crane (*Antigone canadensis*), the barn owl (*Tyto alba*), and the great blue heron (*Ardea herodias*). Alaksen protects important habitats for overwintering and migrating birds as part of the network of Pacific coast habitats that stretch from Siberia to South America. Since 1995, it has been reported that the area has seen an increase in populations of migratory birds, the most prominent being waterfowl, notably Lesser Snow Geese (*Chen caerulescens*) (Pacific Flyway Council 2006).

Traditionally lesser snow geese populations occupied the coastal marshes of the Lower Fraser River, feeding on seed, rhizomes, and wild grasses (Van Eerden et.al. 2005). In the past thirty years, many farms in the Delta area have shifted from a mixed farming practice (integrating forage and livestock production) to vegetable production (Odhiambo et.al. 2012). Subsequently, geese populations began to actively feed on potato residue and cover crops, resulting in a major shift in bird diet (Hatfield 1991). This dietary shift maximized energy and protein intake resulting in an improvement in the overall fitness, decreased mortality, improved body conditions, and increased mean number of offspring (Owen et.al. 1991, Fox et.al. 2017). This increase in the numbers of birds has resulted in a potential negative impact on habitat within and outside of the boundaries of Alaksen.

Like Alaksen, other wildlife areas supporting migratory bird populations in the Pacific Flyway are been significantly impacted by changes in farming. In many cases, diversified farming operations, with their pastures, hay meadows, grassy fence rows, hedgerows, wetlands, and riparian areas are being replaced by monoculture operations of specialized commodity crops (Jackson 2002). Despite the importance of these agricultural landscapes as habitat for migratory birds, little attention has been paid to the impact of changing farming practices, and the fragmentation of habitat that is occurring (Jackson 2002).

Alaksen demonstrates how agricultural landscapes, and land management practices play an important role in supporting wildlife populations. Strategies for conciliating farming and ecological outcomes, including habitat preservation, will be critical as habitat is lost to urbanization, and climate change alters regional weather patterns. It will require cooperation between conservationists and farmers to ensure the viability of agriculture and improve ecological integrity. Integrated planning should involve the effective management of conservation activities, while simultaneously attaining socially, environmentally, and economically viable farm operations. Critical habitat areas, like Alaksen, present a challenge for land managers who must develop a plan for the accommodation and remediation of the resultant impacts of increased migratory bird use. A better understanding of the current conditions of this agro-ecological system will allow managers to explore options for viable farming operations that could build environmental resilience and ecological function within the wildlife protected area. A clear understanding of current agronomic practices, and their impact on wildlife within Alaksen is needed for the development of a collaborative framework to sustainably manage multiple ecosystem services.

This study was commissioned by the Canadian Wildlife Services (CWS) to better understand the relationship between farming activities and wildlife habitat and food provision, and the potential options to improve multiple management objectives within the protected area. Specific objectives of this baseline assessment were to:

1. Review and document the current agronomic practices within Alaksen.
2. Conduct a preliminary assessment of how these practices might be impacting habitat and associated wildlife, and identify which practices are most likely to realize multiple ecological objectives of the protected area.
3. Provide recommendations for research to support the development of an agricultural management plan to enhance ecological integrity and services at Alaksen.

This report consists of a comprehensive literature review of studies conducted within the protected area and neighboring agricultural areas, results from a series of interviews with key stakeholders involved with agricultural practices and wildlife management at Alaksen, and preliminary analysis of seven years of bird surveys coupled with crop management data. The report will serve as the basis for the conceptualization of a long-term, comprehensive, and incremental research strategy designed to inform and guide the enhancement of the existing Alaksen agricultural management plan.

2. Methods

From January to March 2018 Alaksen farmers were asked to participate in a series of interviews designed to collect baseline information on a wide range of agronomic practices including crop rotations, pest management, and soil fertility management (Appendix A). We also contacted their contracted Integrated Pest Management (IPM) consulting company, ES Cropconsult, to obtain detailed information about the IPM programs employed.

We used bird counts from the 2011-2017 Winter Waterbird and Great Blue Heron Foraging Surveys (CWS unpublished) conducted at Alaksen to assess relationships between bird habitat use and crop type. For the Survey, Alaksen was divided into four quadrants, each containing several parcels of land of known habitat types (Figure 3) (CWS unpublished). The surveys recorded the number of birds on a field, categorized by species type, and were conducted between October and March of each year. For the purpose of habitat type identification, agricultural fields were categorized as “Cultivated fields” or “Grassland/Old Field”. Using the crop rotation schedule provided by CWS, we were able to subdivide these two habitat categories into six different subcategories of cropping combinations that would be grown within a field or clusters of fields at any given time, depending on the stage of the crop rotation: cabbage, potato, grass (forage or cover crops), cabbage/grass, potato/grass and potato/cabbage/grass. Given that the CWS bird observations were all made for clusters of fields (i.e. groups of fields adjacent to each other), we analyzed the association between bird numbers and crop type at the scale of the field, when isolated, or field clusters.

Bird abundance, an indicator of habitat use, was estimated by dividing the number of birds per group recorded in a field by the area of that field. Average abundance of birds was calculated by dividing bird abundance in a field by the number of observations recorded in that field between 2011 and 2017. We compared these results with preliminary findings of a 2016-2017 Avian Count Survey conducted by The Delta Farmland and Wildlife Trust (DF&WT) to assess patterns of habitat use and crop type preference of avian populations in the surrounding Delta area (Deare et.al. 2017, unpublished).

We completed a comprehensive literature review of peer-reviewed research in the Delta area, and grey literature published over the last twenty-five years. In addition, we examined the results of similar studies conducted within the Pacific Northwest Bioregion (Washington and Oregon State coastal areas), and California for comparison. We also contacted a number of similarly managed US National Wildlife Areas located in western Washington and Oregon to explore and document alternative farming and wildlife management approaches within our bioregion.

Figure 1: Map of agricultural fields at Alaksen NWA (Google Maps 2018)

3. Farming in the Alaksen

3.1. Field Characteristics and Farming Operations

Agricultural fields at Alaksen have variable size, shape, topography, drainage, and microclimate. Fields range in size from 6.7 to 70 acres (Table 1) and are mostly separated by buffer strips and hedgerows. Field edge areas are a relatively ecologically complex mix of woody vegetation and grasses and serve as important habitat for small mammals, birds and arthropods (Figure 1).

Three family farms operate in Alaksen: Emma Lea Farms, Swenson Farms, and Felix Farms (Table 1). These families have been farming the land for many years. As a result, they have substantial knowledge of the land and have developed their agricultural practices accordingly.

Table 1: Field numbers, field area, commercial crops, drainage status and farm operations in Alaksen

Field #	Number of Acres	Crop Rotation	Drainage*	Farm Operation
1N	20	Vegetables/Forage	Good	Emma Lea Farms/Swenson Farms
1E	20	Vegetables/Forage	Good	Emma Lea Farms/Swenson Farms
1W	20	Vegetables/Forage	Good	Emma Lea Farms/Swenson Farms
1S	10	Vegetables/Forage	Poor	Emma Lea Farms/Swenson Farms
2N	25	Vegetables/Forage	Good	Emma Lea Farms/Swenson Farms
2S	10	Vegetables/Forage	Good	Emma Lea Farms/Swenson Farms
3	35	Vegetables/Forage/Livestock	Good	Emma Lea Farms/Swenson Farms
4	22	Vegetables/Forage/Livestock	Good	Felix Farms
5	23	Vegetables/Forage/Livestock	Good	Felix Farms
6	40	Vegetables/Forage/Livestock	Poor	Felix Farms
14E	22	Vegetables/Forage/Livestock	Poor	Felix Farms
14W	23	Vegetables/Forage/Livestock	Poor	Felix Farms
15	32	Vegetables/Forage/Livestock	Poor	Felix Farms
16	6.7	Forage/Livestock	Poor	Emma Lea Farms/Swenson Farms
17	19	Vegetables/Forage/Livestock	Poor	Emma Lea Farms/Swenson Farms
18	12	Vegetables/Forage/Livestock	Poor	Emma Lea Farms/Swenson Farms
19W	8	Forage/Livestock	Poor	Emma Lea Farms/Swenson Farms

* Determined by farmer observations reported in the interviews

Felix Farms is owned and operated by the Guichon family. The family runs a well-established potato operation on six fields in the protected wildlife area, one of which is split into two distinct rotations (Table 1). Emma Lea Farms and Swenson Farms are owned and operated by Kevin Husband and Rod Swenson respectively. The two families collaboratively farm on seven fields within the wildlife area, three of which are divided into subfields. Swenson Farms is a potato production operation. Emma Lea Farms is a diversified operation that includes production of cabbage, rutabaga, beet, forage, and dairy cattle within the boundaries of Alaksen, and strawberry and blueberry production outside the protected wildlife area.

3.1.1. Crop Rotations

Crop rotations in agroecosystems are planned sequences of different crops, cultivated over time, on the same field. This is a common agronomic practice used to break crop pest cycles, increase soil organic matter, improve soil quality and fertility, and to protect water quality. Farming operations at Alaksen utilize a five-year crop rotation, but given the additional objectives of the protected area, their design also includes the ongoing provision of important sources of food and habitat for wildlife. While the specifics of the crop rotation vary in terms of timing and crop species, Alaksen farming operations follow a general pattern of two consecutive years of summer vegetable production, followed by three consecutive years of mixed grass (forage) used for livestock production (Table 2). In the years in which vegetables are grown, farmers establish a cover crop in the fall, ostensibly to protect the soil from erosion and provide habitat and food for wildlife during the winter.

3.1.2. Vegetable Production

Potato (*Solanum tuberosum*) is the main cash crop in the Delta, and are grown on approximately 22% of the agricultural land base (Yates 2014). Potato production at Alaksen takes place between May and early October, although this has changed over the last few years due to variable weather patterns in the region. The production of cabbage (*Brassica oleracea*), rutabaga (*Brassica napobrassica*) and beet (*Beta vulgaris*) takes place between May and late-August (Table 2).

Table 2: Typical five-year vegetable/forage crop rotation by year and month

YEAR 1 Jun to Sep	YEAR 1-2 Sep to May	YEAR 2 Jun to Sep	YEAR 2-3 Sep to May	YEAR 3 May	YEAR 4	YEAR 5 Sep
CASH CROP potato	**COVER CROP** fall rye, winter wheat, barley	**CASH CROP** cabbage. rutabaga, beets Potato	**COVER CROP** fall rye, winter wheat, barley	**FORAGE** orchard, fescue, timothy	**FORAGE** orchard, fescue, timothy	**FORAGE** orchard, fescue, timothy

Irregular and variable patterns of precipitation over recent decades, have prevented early spring establishment and early fall harvest of summer crops, which poses major challenges to farmers trying to meet their expected production targets under shorter growing season conditions (Neufeld et.al. 2017). As climate change continues to shift precipitation patterns (British Columbia Ministry of the Environment 2016), crop production is expected to become more challenging, and yields may decline affecting the economic viability of farming in Delta. Additionally, lower crop yield and delayed cover crop establishment have the potential to negatively impact food supply for overwintering, and migratory bird populations.

3.1.3. Forage and Pasture Production

Following two years of vegetable and cover crop production, Alaksen farmers plant a mix of three grass species: orchard grass (*Dactylis glomerata* cv. Amba); tall fescue (*Lolium arundinaceum* cv. Courtney), and timothy grass (*Phleum pratense* cv. Titan) (Table 2). Most fields remain under grass production for three consecutive years. During the first year of forage production, grass is sown sometime in May and left uncut during the summer. According to farmers, this practice allows plants to establish a strong root system, capable of withstanding intense grazing by bird populations during the winter. Farmers report that between October and April, birds feed intensively on forage plant foliage, leaving the crowns and roots intact, and that the thick mat of roots and crowns protect the soil from erosion, compaction and sealing by bird traffic. During the subsequent two years, farmers will make two or three cuts during the growing season (depending upon growth) to produce baled hay, and will allocate part of this forage to pasture for grazing dairy cows. Because grass is repeatedly harvested or fed upon by both livestock and waterfowl, plants remain short over the winter, with young and succulent leaves that are more palatable and appealing to waterfowl (Bradbeer 2012).

3.1.4. Winter Cover Crops

Winter cover crops at Alaksen are typically established between mid-September through early October following the harvest of summer vegetables. The planting time has gotten later over the last years as a result of variable weather patterns in our region (presumably due to climate change) (Table 2). Over the years, farmers have been planting a variety of cover crop cultivars, such as barley (*Hordeum vulgare*), winter wheat (*Triticum aestivum*), and fall rye (*Secale cereale*). These cultivars have been selected for their ability to germinate at low temperatures, and to produce higher biomass yields than other annual cover crops used for overwinter soil protection (Odhiambo et.al 2012). Farming operations differ in the sowing time and methods: fall rye is sown in rows using a seed drill (Emma Lea Farms); and winter wheat and barley are broadcasted directly into the fields (Swenson Farms and Felix Farms). In addition, Felix Farms intercrops forage with barley during their first summer of forage production, allowing it to grow into a tall canopy over the summer.

A number of studies indicate that late seeding leads to the poor establishment of cover crops, resulting in a weak canopy (Odhiambo et.al. 2012). A better understanding of the rate of establishment and bird consumption of these cover crops could help farmers and managers explore alternative management practices aimed at maintaining the cover crops during the winter months.

3.2. Agricultural Pest Management

Pests are organisms that restrict the availability, quality and value of agricultural crops. Agricultural pests can include arthropods (insects and mites), pathogens (fungi, bacteria, viruses), vertebrates (e.g. birds and rodents), mollusks (e.g. snails and slugs), and plants (weeds) (Flint 1997). Pests impact the economic viability of the farming operations by reducing crop yield and/or increasing the costs of production. During our interviews, farmers expressed that management of pests is always a concern, and they are aware that changes in seasonal patterns may alter patterns of pest occurrence in unpredictable ways. Farmers also expressed their desire to utilize more ecologically based and environmentally sound pest management methods.

For thirty years, farm operators have used the services of E.S. Cropconsult, a local Integrated Pest Management (IPM) consulting company, to monitor and provide management recommendations for pests affecting their crops. Heather Meberg, President and Director of Services, has been working with farmers in Delta for more than twenty-five years. In her experience, pest pressure and occurrence at Alaksen is significantly lower than in other farms in the area. According to her, crop rotations disrupt the life cycles of agricultural pests by drastically modifying their environment. Meberg also points out that hedgerows and grass margins around the fields provide important refuge for a host of beneficial insects such as lacewing (*Nearctic Lonchopteridae occidentalis*) and ladybird beetle (Coccinellidae) that help to keep arthropod pest populations under control.

IPM plans for farm operations at Alaksen include the use of broad-spectrum, synthetic pesticides. Over the last decades, however, increasing concern from the public regarding the undesirable effects of such pesticides to human health, non-target species and the environment, has put pressure on both farmers and wildlife managers to utilize alternative pest management methods. This presents a challenge as growing seasons become shorter, precipitation rates increase, and changes in seasonal patterns make pest monitoring more difficult, and outbreaks more challenging to predict and manage.

A better understanding of how pest populations have been affecting farming operations in Alaksen over the years has the potential to help farmers predict and manage future changes in pest populations under new climate conditions. As intensification of crop production increases, well informed planning and implementation of ecologically sound integrated pest management practices will become critical.

3.2.1. Pests Affecting Crop Production

According to Meberg (E.S. Cropconsult) the most damaging arthropod pest affecting potato production at Alaksen is tuber flea beetle (*Epitrix tuberis*) (Table 3). Adults usually overwinter in hedgerows, and grass margins around fields, and move into the fields at the beginning of the spring where they produce up to three generations per season. Also of major importance, due to its pathogenicity, is the fungal disease late blight (*Phytophthora infestans*). Late blight thrives in cool wet weather, typical of the growing season in the Lower Mainland, and can destroy a potato field in only a few days. Due to the severity of this pathogenic disease farmers in the region are required to take preventative measures according to provincial regulation and following guidelines from the BC Ministry of Agriculture.

Secondary insect pests that can occasionally affect potato production include aphids (*Macrosiphum* *euphorbiae, Aphis gossypii, and Myzus persicae*), and thrips (*Frankliniella occidentalis*) (Meberg, personal communication, May 2018). Adult aphids and thrips usually overwinter in hedgerows and grass margins around the fields. Though wireworm (*Agriotes* spp.) is an important insect pest that affects commercial potato production in the Lower Mainland, farmers at Alaksen report no major issues with this species.

The most damaging insect pest affecting cabbage and rutabaga production at Alaksen is cabbage root maggot (*Delia radicum*) (Table 3) (Meberg, personal communication, May 2018). Secondary arthropod pests affecting production include cabbage looper (*Trichoplusia ni*), imported cabbageworm (*Pieris rapae*), diamondback moth (*Plutella xylostella*), and cabbage aphid (*Brevicoryne brassicae*). Adults of these insect pests usually overwinter in crop residue in the fields, hedgerows, and grass margins. Also, of major importance, due to its pathogenicity, is the bacterium causing black rot disease (*Aphanomyces raphani*), which overwinters in crop residue (Table 3).

According to Meberg, there are no major insect or pathogenic pests affecting beet production at this time. During our interviews, farmers reported that pest damage to forage crops is not a concern, and thereof they do not monitor them.

Table 3: Pest by crop type found in Alaksen (ES Cropconsuult, 2018)

Crop	Pest Name	Pest Type
Potato	**Late Blight** *(Phytophthora infestans)*	Fungus
	Potato flea beetle *(Epitrix tuberis),* **aphids** *(Macrosiphum euhorbiae, Thomas and Macrosiphum euphorbiae),* **thrip** *(Thrips tabaci Linnaeus, Frankliniella occidentalis Pergrande)*	Arthropod
Cabbage, rutabagas	**Root maggot** *(Delia radicum L.),* **Looper moth** *(Trichoplusia ni),* **cabbageworm** *(Pieris rapae),* **imported diamond-back moth** *(Plutella xylosstella L.), a***phid** *(Brevicoryne brassicae)*	Arthropod
	Black rot disease *(Aphanomyces raphanin)*	Bacterium
Forage and vegetable crops	**Horestail** *(Equisetum arvense),* **chickweed** *(Stelleria media)*, **lambs quarter** *(Chenopodium spp.)*, **Himalayan blackberry** *(Rubus armeniacus)*, **field mustard** *(Brassica spp.)*, **buttercups** *(Ramunculus)*, **scotch broom** *(Cytisus scoparius)*, **plantain** *(Plantago spp.)*, **Canada thistle** *(Cirsium arvense)*, **nightshade** *(Solarum app.)*, **purple loosestrife** *(Lythrum salicaria)*, **curly dock** *(Rumex crispus)*	Plant

During interviews, farmers reported that weed competition can impact all the crops grown at Alaksen, particularly at the time of establishment. To manage pressure, farmers use a combination of pre-emergent and post-emergence herbicides that they apply during the growing season. Herbicides are used in combination with intensive cultivation of the fields. The use of cover crops during the winter can also help curtail the establishment of weeds. Elsewhere, hedgerows and field margins have been reported as areas where weeds can get established becoming a source of seed for neighboring agricultural fields (Meberg personal communication, May 2018).

3.2.2. Pest Management Strategies

Integrated pest management (IPM) is a multiple tactic/ multiple tool based approach to the management of agricultural crop pests. Management tools fall into four categories: biological, cultural, mechanical and physical, and chemical controls. Biological control involves the use of an organism to reduce the adverse effects of another organism, such as the use of the bacterium *Bacillus thuringiensis* (Bt) to control cabbage white moth (*Pieris rapae*), or ladybird beetle predation on aphid. Cultural controls involve the manipulation of agronomic crops and landscape management practices to decrease pest incidence, and include timing of planting and harvesting, and the use of resistant cultivars. Mechanical and physical controls are measures taken to kill the pest directly or indirectly, or exclude the pest. Examples include pest barriers (row covers), tillage, and cold storage of products. Chemical controls involve the use of pesticides. In advanced, ecologically based, IPM programs, biological, cultural, and mechanical and physical control mechanisms are preferred and use of pesticides is considered the tactic of absolute last resort (Flint 1997, Pest and Pathogen Control Through Management of Biological Control Agents and Enhanced Cycles and Natural Processes Committee et.al. 1996).

Farmers at Alaksen reported using a combination of cultural practices (i.e. crop rotations, resistant cultivars), and chemical controls (i.e. pesticides) to manage pest populations. E.S. Cropconsult monitors vegetable production fields weekly during the growing season. Whenever scouts detect the presence of problematic pest populations in a field, the company will issue a series of pest management recommendations that include optimal timing and recommended rates for therapeutic pesticide application. Following these recommendations, farmers will conduct localized “spot” applications on the affected area of the field or fields to keep target pest populations below economic injury levels. In addition, farmers will conduct field-wide prophylactic fungicide applications throughout the summer to prevent the occurrence of the potato fungal pathogen late blight. Table 4 presents a list of pesticides used by Alaksen growers and their usual application times.

It is valuable to note that E.S. Cropconsult has kept records of all the recommendations they have issued over the last thirty years. These reports include important information about pest populations. This information could be used to develop predictive models to anticipate potential changes in pest populations resulting from climate change. Such models could guide the development and implementation of management practices that will help mitigate the impact of changes in pest population patterns.

Table 4: Typical pesticides and their application times used by Emma Lea Farms, Swenson Farms, and Felix Farms

Crop	April	May	June	July	August	September
Potato	Lorox (Herbicide) Sencor (Herbicide) Gramoxone (Herbicide)	Malathion (Insecticide)	Curzate (Fungicide) Bravo (Fungicide) Acrobat (Fungicide)	Tatoo (Fungicide) Forum (Fungicide) Gravel (Fungicide)	Forum (Fungicide) Reglon (Top Kill) Dessica (Dessicant) Bravo (Fungicide)	
Cabbage, Rutabaga, and Beets	Rival (Herbicide) Lorsbam (Insecticide) Ripcord (Insecticide)	Movento (Insecticide)	Ripcord (Insecticide) Movento (Insecticide) Closer (Insecticide) Bravo (Fungicide)	Closer (Insecticide) Moventio (Insecticide) Quadris (Fungicide)	Moventio (Insecticide)	Ripcord (Insecticide)
Forage	Gramoxone (Herbicide)	Gramoxone (Herbicide)				

3.3. Soil, Water, Drainage and Nutrient Management

Soils at Alaksen belong to the Crescent soil management group, mainly in the Westham soil series. The texture of these soils is silt loam. They are moderately to poorly drained, naturally acidic (pH ranging between 5.0 and 6.0), and prone to remain saturated at the root zone until the late spring. As a result, early cultivation of crops is usually delayed until mid-spring (Bertrand et.al. 1991).

Although one of the most agriculturally productive areas in Canada, farm yields in Delta are thought to be far below their productive potential (Klohn et.al. 1992). Studies indicate that this may be associated with a number of soil related issues that are driven by inadequate sub-surface drainage, deep soil compaction, and inadequate soil management practices (Odhiambo et.al. 2012). The continuous use of detrimental soil management practices, such as intense tillage or working the soil under very wet and dry conditions, have been linked to the degradation of soils in the area (Neufeld et.al. 2017). In addition, a shift from forage and livestock production to cultivated vegetable production may have decreased the accumulation of soil organic matter in the Delta soils over time (Odhiambo et.al 2012). Soil organic matter is an essential component of soil quality, it improves drainage, aeration, water retention, and nutrition storage/cycling.

In spite of their importance, the impacts of agricultural management practices on soil quality have not been studied in detail within Alaksen. Additional factors, such as drainage and irrigation, that could also impact the long-term sustainability of the soil, need to be considered.

3.3.1. Drainage

Some of the management challenges related to soils in the Delta area are associated with poor drainage. Factors such as soil texture, position below sea level, high-water table, and high precipitation rates keep some soils saturated during the winter and early to mid-spring. Many farm operations rely on infrastructure (such as drain tiles) for saturation-free root zones during time of crop establishment (Bertrand et.al. 1991), and to reduce prolonged waterlogged conditions during the spring (Hermawan et.al. 1996). Farmers at Alaksen are reluctant to consider installing infrastructure as an option for addressing drainage issues. Some of the major perceived challenges include damaging or reducing hedgerow and grass margin habitat during installation, and recouping the substantial investment.

According to Alaksen farmers, poor drainage has led to the salinization of fields 8, 9, 19.1 and part of field 6. As a result, these fields have been taken out of production and remain “abandoned”. Farmers argue that poor drainage has contributed to the surface accumulation of salts from summertime irrigation, in addition to saltwater intrusion from high water tables. These factors can be exacerbated in Delta where the salinity of irrigation water from the Fraser River is tidally influenced (Neufeld et.al. 2017).

To improve surface drainage conditions, farmers at Alaksen resort to a combination of low cost, low maintenance drainage improvement methods. These include subsoiling (using a deep shank plow to break up the compaction layer), surface drainage through natural or constructed channels, or modifying the topography to allow the flow of water from fields into ditches. Ditches and sloughs are the most common surface drainage infrastructure used by farmers at Alaksen. Ditches are well suited for the wildlife area due to their low cost, their capacity to evacuate large volumes of water, ease of construction, and the additional provisioning of habitat for birds, insects, amphibians, fish, and mammals. However, they do require a great deal of maintenance, are subject to sedimentation (silting in from farm field erosion), pesticide runoff contamination, and take up area that would otherwise be dedicated to terrestrial habitat or agricultural production. Ditches within the protected area range in size from 1 to 1.5 m wide, with an average depth of 1m. Water collected in ditches is evacuated through connectors leading to a main system of sloughs. Sloughs lead to the Fraser River and are periodically maintained by CWS.

Drainage management challenges related to soils in the Delta area are also linked to the percentage of organic matter present in the soils. Organic matter facilitates water infiltration by increasing the proportion of large pore spaces in the soil. A decrease in organic matter as a result of adverse soil management practices can result in increased soil compaction, surface ponding, and loss of soil surface structure (Odhiambo et.al. 2012).

As poor drainage conditions pose serious limitations to crop productivity at Alaksen, how soil management practices are affecting and are affected by drainage issues is critical to understand and address.

3.3.2. Irrigation

Irrigation of commercial crops at Alaksen is facilitated by drawing water from a system of sloughs and ditches filled from the Fraser River. Irrigation is usually utilized between June and the end of July. Water moves into the slough-ditch system by hydraulic pressure and it is distributed along the fields by a system of flood boxes, gravity outlets and water pumps. During the growing season, and because salinity of the water is tidally influenced, farmers must monitor salt levels going into the sloughs, and rely on a system of gates to protect the irrigation canals from extremely salty water. By the end of July, salinity concentration in the incoming waters of the Fraser River increases to levels that are toxic to crops, and Alaksen farmers need to close the slough gates for the remainder of the season, which precludes further irrigation. This has presented challenges during years of drought.

Irrigation practices in farming operations influence, and are also influenced by the percentage of organic matter in the soil. Adding organic matter to the soil by cover cropping or with addition of manure or compost, increases the water holding capacity of soils, reducing the need for irrigation. Despite its importance, the impact of soil organic matter management on irrigation requirements has not been studied at Alaksen.

During our interviews, farmers expressed great concern regarding plans to deeply dredge the Fraser River (to allow large scale vessel traffic), anticipating changes to the quality of the water they use for irrigating their fields as a result. Investigating the implementation of alternative methods of water conservation, storage and filtration could help address current irrigation issues, such as increasing salinity, and support the development of a robust water management plan that addresses future water dynamics, and mitigates changes in water quality.

3.3.3. Nutrient Management

Farmers engage in nutrient management determining the amount, source, method of application, and timing of soil amendments that go into their fields for the growing season (Natural Resources Conservation Services 2012). A well-designed nutrient management plan protects the local and regional water resources from contamination by preventing excess nutrient leaching and runoff (mainly nitrate, nitrogen and phosphorus), and enhances farm profitability. Every year, farmers at Alaksen conduct soils analyses to determine the levels of essential nutrients present, and for the calculation of amendments. Essential nutrients are held on soil colloids, and for most crop plants, become soluble and thus more available to plants between pH 6.0 and 6.5 (slightly acidic). Because soils in this area are naturally acidic (pH < 6.0), Alaksen farmers rely on liming (application of calcium carbonate or similar materials) to raise the pH levels of their soils. This is usually done at the beginning of the five-year rotation plan. By keeping the soils at an appropriate pH, the amount of fertilizer needed/applied can be reduced. Nutrient leaching (loss into groundwater) and volatilization (loss to atmosphere) are also reduced.

Fertilizer applications take place in the spring, before potato, cabbage, beet and rutabaga planting.

Farmers use a combination of synthetic fertilizers to replenish the nutrients lost from crop removal, leaching and soil surface runoff. Application of fertilizers to forage fields takes place during the months of May and August. While synthetic fertilizers provide the necessary nutrients for plant growth, they do not recycle nutrients effectively and often have a low nutrient-use-efficiency (Gliessman et.al. 2015). Organic amendments (i.e., composts and manures), by contrast, can cycle the nutrients more effectively, and increase soil organic matter thus reducing the amount of nutrient runoff and the need for external nutrient inputs (Gliessman et.al. 2015). Farmers at Alaksen do not apply compost or manure amendments to their soils, however, fields under livestock production receive small amounts of cow manure during grazing, and bird droppings during the winter.

Thus far, the amount of nutrient inputs that go into the soils (synthetic fertilizers and livestock/bird inputs), and their relative role in nutrient cycling has not been examined in detail. An integrated system, such as Alaksen, which combines some organic inputs with synthetic fertilizers, may be more difficult to manage effectively given the use of multiple amendment inputs with differing mineralization modes and rates, and nutrient availabilities. A better understanding of these inputs and their nutrient contributions could help in the development of a long-term nutrient management plan that incorporates changes in weather due to climate change and meets the multiple objectives of the protected area and farmer alike.

3.4. Crop and Livestock Integration

Livestock integration is an integral component of Alaksen farming and affects the crop rotation schedule. Under the current system, forage fields used for livestock production are categorized as being “pasture”. Emma Lea Farms manages a 60 to 80 head dairy herd. Every summer cows are rotated between 11 fields (Table 1). These fields are equipped with the fencing and gates required to contain the animals. The herd is moved to shelters for the winter around the beginning of October. The integration of livestock with crop production is a common agricultural practice that is used to reduce weed pressure, soil disturbance and associated compaction; improve soil structure and water infiltration; improve soil fertility, and increase yield of subsequent crops (Gliessman et.al. 2015). However, animal traffic has been linked to soil compaction (Bell et.al. 2011), and greenhouse gas emissions, mainly methane and nitrous oxide, resultant of the animals’ digestive process and the decomposition of manure (Food and Agriculture Organization of the United Nations 2009).

Despite being an integral component of the rotation schedule, the impacts of livestock integration at Alaksen are poorly understood. Determining these impacts can help managers better understand the nutrient cycles driving soil heath and soil fertility of the agroecosystem. A broad perspective, taking into account the benefits as well as adverse effects of these interactions, is needed to determine the impacts and efficacy of crop-animal integration system in sustaining biodiversity and crop productivity at Alaksen.

4. Potential Impacts of Agricultural Practices on Wildlife and Their Environment

Agriculture at Alaksen confers a significant number of ecological functions within the wildlife area. The role these practices play in the sustenance of wildlife populations however, is not fully understood. In this section, we examine agricultural practices and landscape features (such as field size) to assess their bearing on the provision of two primary requirements, food and habitat, to migratory bird populations. We compare CWS Waterbird Survey data with the crop rotation schedule to determine patterns of bird crop preference, abundance and diversity.

4.1. The Establishment of Winter Cover Crops

One of the primary challenges at Alaksen is posed by the current selection of crops grown which results in late season cover crop establishment. Farmers in Alaksen have reported that over the last decade, their harvest dates have been delayed to the beginning and/or the middle of October, ostensibly due to later planting as a result of increasingly wet conditions in the spring. Consequently, farmers are now

Figure 2: Photos of field 5 (forage) and field 4 (cover crop) illustrating differences in ground cover by early spring April 2018

seeding their winter cover crops at the end of October, whereas previously they could harvest their crop and plant cover by the first week of September, when conditions for establishment are more favorable. Studies conducted in the Delta area indicate that winter cover crops sown in late September result in underdeveloped root systems and poor biomass production (Nafuma 1998, Odhiambo 1998). In addition, Alaksen farmers convey that severe removal of foliage, stolons, roots and other plant parts by migratory and overwintering populations of waterfowl often impede adequate establishment the of young plants. Our field observations (2018) indicate most of the fields that were planted with cover crops during the fall ended up bare by the end of winter (Figure 2). Fields with reduced vegetative cover remain exposed and vulnerable to erosion over the winter. As a result, degraded fields may experience uneven seed germination, poor crop establishment, and crop failures (Odhiambo et.al. 2012). This has the potential to affect soil quality and lower the quality of habitat for overwintering and migratory birds that rely on cover crops as a food source, and habitat to build their nests (Bradbeer 2007, Hatfield 1991). This negates many of the positive agronomic and ecological impacts of including winter cover crops in the rotation.

Although, management records indicate that Alaksen farmers have been planting cover crops consistently, there is no data to show the extent to which these plantings are establishing or persisting through the winter (providing critical feed for waterfowl and cover for the soil).

Once feed and habitat resources become scarce, birds are forced to look for sustenance outside of the boundaries of Alaksen (Bradbeer 2007). In the last few years, reports of birds feeding in the agricultural lands of Surrey and Langley are becoming more frequent (D. Bondar, DF&WT, personal communication. March 2018). As populations move outside of their protected feeding areas, conflict with human operations increases. A report by Zbeetnoff et.al. (2004) conveys that forage feeding by birds leads to significant economic losses for producers in the Delta region. Additionally, as farmers in the southwest British Columbia shift from forage and vegetable crop production to perennial berry production, there is concern among forage farmers and conservationists regarding impending shortage of food sources for migratory waterfowl (D. Bondar, DF&WT, personal communication. March 2018). These changes are exacerbated by the fact that a few subspecies of Canada Goose (*Branta canadensis)* have interbred to form a resident population that feeds intensively on native vegetation once the crop residue and cover crops food sources have been depleted (E. Balke personal communication. Aug 2018).

The absence of a cover crop over the winter has also been correlated with deterioration of water quality and aquatic wildlife. Nonpoint source (NPS) agricultural field nutrients, soil sediments, animal wastes, salts, and pesticides are the leading contributor to water pollution in rivers and lakes. They are also the second largest source of degradation to wetlands, and a major contributor to contamination of estuaries and groundwater (Ongley 1996). Activities that cause water pollution from farm operations include overgrazing, improper, excessive or poorly timed application of pesticides, irrigation and fertilizers, and practices that cause soil erosion by water, such as lack of vegetative cover (Ongley 1996). Without vegetative cover, rainfall can cause soil particles to dislodge and/ or the soil surface to become impermeable (sealed), increasing surface runoff of water laden with soil particles and pollutants into nearby waterways, and reducing organic matter incorporation into the soil (Ongley 1996). In the case of Alaksen, waterfowl traffic around ponded areas in fields, further contribute to soil surface sealing as they walk on saturated soils (Principe 2002). In fish bearing waters (impacted by soil erosion) large amounts of sediment can cloud the water, reduce the amount of sunlight that reaches aquatic plants, and can clog the gills of fish or smother fish larvae (Ongley 1996). In addition, other pollutants such as fertilizers, pesticides, and heavy metals often attach to soil particles that wash into water bodies, causing algal blooms and depleted oxygen conditions, which can prove deadly to most aquatic life (Ongley 1996).

Alaksen farmers reported observing a substantial accumulation of soil sediment in adjacent sloughs affecting drainage and irrigation functions for the entire drainage network. To date, the potential levels of ecological toxicity of run off material and accumulating sediments on aquatic wildlife at Alaksen has not been assessed.

Improving cover crop establishment and subsequently soil cover on Alaksen farm fields could have important benefits for both wildlife and the sustainability of agricultural production. There have been a number of studies that have investigated the use of different cover crop species and cultivars in terms of their ability to establish and rapidly produce significant biomass, and survive under cold conditions (Odhiambo et.al. 2012). While some died after the first frost, others produced adequate winter cover, and produced significant biomass in relatively cold growing conditions (Odhiambo et.al. 2012). Identifying cover crops that are best suited for the changing weather, cropping conditions and wildlife feeding pressure could help ensure that this important resource is maintained throughout the winter. Alternatively, there may be changes in cropping practices that could increase cover crop success. To this end, others provide direct insight to Alaksen in regard to cover crop management. For example, in the nearby Skagit Wildlife Area (in Washington State, USA), an agriculturally managed wildlife area that is used by migratory birds, and shares many similarities with Alaksen, farmers are required to plant cover crop by September 15 of each year following harvested crops. This enables the effective establishment of wintering forage resources for swans and other waterfowl (Washington Department of Fish and Wildlife 2017) (Appendix B). In California, the Department of Fish and Wildlife (CDFA 2016) has developed a State Wildlife Action Plan (SWAP) that includes a comprehensive Agriculture Companion Plan for the development of a collaborative framework to sustainably manage ecosystems across the state in balance with human uses of natural resources. CDFA engages farmers by promoting environmental stewardship through several initiatives, including the Healthy Soils Initiative, and the State Water Efficiency and Enhancement Program. Developing this type of guidance for Alaksen farmers would require a detailed analysis of cover crop and cash crop options, as well as farmer engagement, but could result in important improvements to the protected area's potential to meet its multiple objectives.

Understanding how currently used cover crop cultivars and sowing practices at Alaksen impact the establishment, and biomass productivity of cover crops has the potential to substantively inform the development of an integral management plan. Such a plan could, in the face of changing weather and hydrological patterns, improve carrying capacity of the protected area, and increase agroecosystem resilience.

4.2. The Relationship Between Crop Selection, Field size and Bird Abundance

Between 2011 and 2017 the Canadian Wildlife Service (CWS) conducted waterfowl, shorebird, and raptors surveys at Alaksen to evaluate applied management activities and improve strategies to meet the goals of the Management Plan (Figure 2). We combined data from this study with information obtained from the Alaksen crop rotation records, to assess patterns of habitat use and crop preferences by avian populations at Alaksen.

Figure 3: Total number of birds observed in the winter waterbird surveys at Alaksen NWA, 2012 to 2017 (Hedderson 2017)

4.2.1. Patterns of Bird Abundance by Crop Type

We used bird counts from the 2011-2017 Winter Waterbird and Great Blue Heron Foraging Surveys (CWS unpublished) conducted at Alaksen to assess relationships between bird habitat use and crop type. For the surveys, Alaksen was divided into four quadrants, each containing several parcels of land and known habitat types (Figure 3) (CWS unpublished 2017). The surveys recorded the number of birds on a field, categorized by species type, and bird counts were made between October and March of each year. For purpose of habitat type identification, agricultural fields were categorized as “cultivated fields” or “grassland/old field”. Using the crop rotation schedule provided by CWS, we were able to divide these two habitat categories into six different sub-categories of cropping combinations that would be grown within a field or clusters of fields at any given time, depending on the stage of the crop rotation: cabbage, potato, grass (forage or cover crops), cabbage/grass, potato/grass and potato/cabbage/grass. Given that the CWS bird observations were all made for clusters of fields (i.e. groups of fields adjacent to each other), we analyzed the association between bird numbers and crop type at the scale of the field, when isolated, or field clusters.

Preliminary analysis indicates that the highest abundance of birds observed throughout the survey was recorded in grass fields (forage), except for 2011 and 2015, when cabbage and potato, and potato/cabbage/grass were the respectively highest (Figure 4). In 2015 bird count in the potato/cabbage/grass field cluster (fields 1N, 1C, and 1S) was 30% higher than the other crop types, but it is unclear whether any of these crops types had a particular role in attracting birds or, whether it was the combinations of crop types or, something else entirely, that contributed to these high numbers.

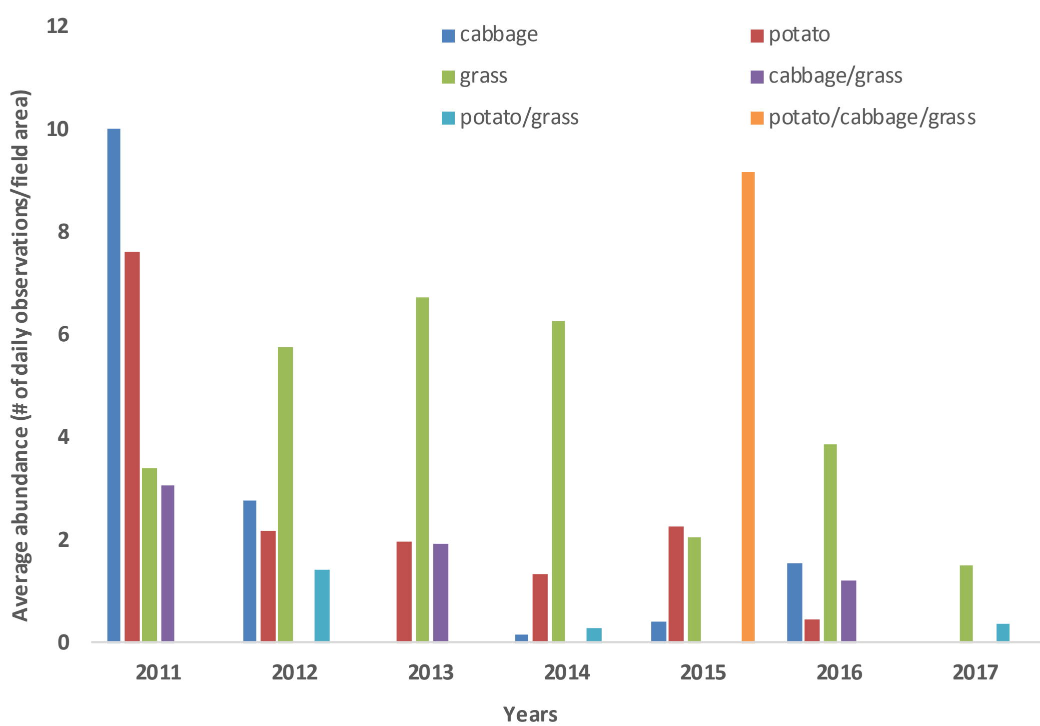

Figure 4: Average abundance of birds (number of daily observations/field area) by crop type during the fall and winter (generally October through March) per year (November 3, 2011 to February 28, 2017)

Our analysis of crop type by avian group reveals differences in patterns of crop preference among groups (Figure 5). Waterfowl showed a preference for potato/cabbage/grass, followed by grass, potato, cabbage/grass and cabbage. Shorebirds too, showed a preference for fields that included potatoes. All other avian groups seem to show a preference for fields that were dominated by grass production. Songbirds and Others were almost entirely observed in grass fields. Raptors seemed to follow the patterns of crop preference shown by the other avian groups with a preference for grass, but the number of raptor observations were very low.

Result of the Avian Count Survey conducted by the DF&WT between 2016 and 2017 showed a similar pattern of distribution, with waterfowl showing preference for potato and cereal cover crops, followed by grass fields (Deare et.al. 2017 Unpublished). Crop preference by waterfowl can also vary between fall and winter. Several studies suggest that waterfowl populations, such as snow geese (*Chen caerulescens*), select potato and cover crops to obtain the crude protein (cover crops) and simple

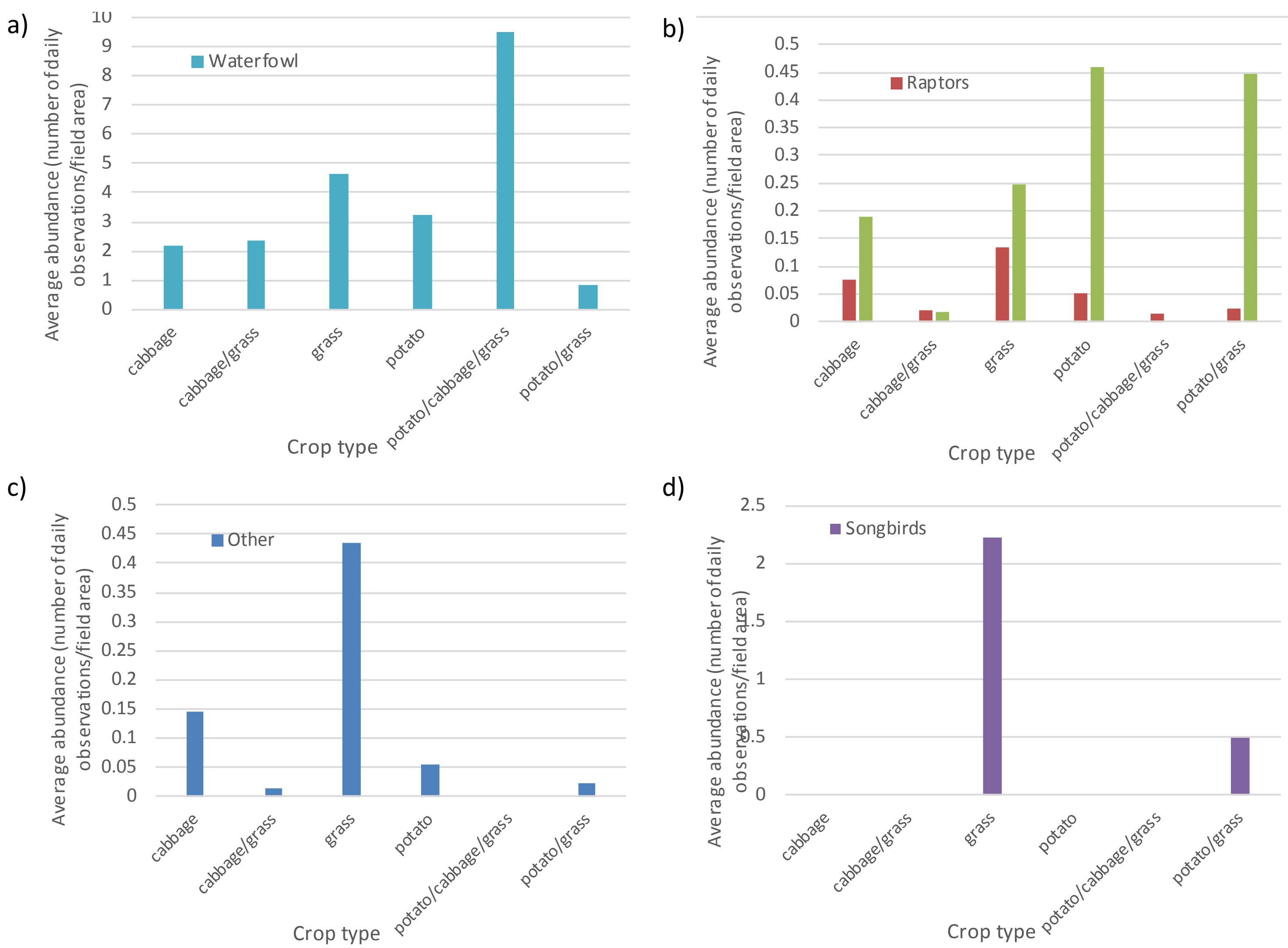

Figure 5: Average abundance of birds (number of daily observations/field area) by crop type during the fall and winter (generally October through March) per year (November 3, 2011 to February 28, 2017) for (a) waterfowl, (b) shorebirds and raptors, (c) others (which includes different species of quails, woodpeckers, and crows) and (d) songbirds.

carbohydrates (potatoes) they need during the fall to repair and rebuild tissues damaged during their migration (Bradbeer 2007, Fox 2017, Owen 1991). Sometime during the winter months, birds shift to a diet based mainly on grass, higher in protein, in preparation for their reproductive period (Fox 2017). Birds continued to feed on forage fields in March and April, possibly due to the presence of young and tender grass shoots at the beginning of the spring (Bradbeer 2007).

Our results suggest that raptors might be attracted to fields where birds are feeding on crop residue and grass, or perhaps where there is greater abundance of small mammals (Figure 6). Hunting bald eagles, (*Haliaeetus leucocephalus*), for example, are known to feed on smaller birds feeding on winter cover crops (Bradbeer et.al. 2012). Northern harriers (*Circus cyaneus*) prefer open habitats such as grass fields, sloughs, beaches, and mud flats where they feed on small mammals, and usually avoid cultivated fields for hunting (Butler 1992). Winter crops covers are also key to providing roosting habitat for a number of raptor species (Butler 1992). The short-eared owl (*Asio flammeus*), a species of Special Concern per the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), use winter cover crop fields as roosting habitat, and are known to roost communally in the winter on the ground in tall grass, shrubs, or hedge rows (Cooper et.al. 2004). Given its role supporting these populations, a decline in winter cover crop biomass at Alaksen may pose significant restriction on the number of raptor nests the wildlife area can support. This may be exacerbated by forage harvest practices. Most studies indicate that grassland bird declines are attributed to the changes in grassland management, in particular, cutting (mowing for hay), since it causes a deterioration of the grassland as nesting habitat, and a degradation of habitat quality by loss of seed and invertebrate resources (Perlut et.al. 2008, Vickery et.al. 2001).

4.2.2. Patterns of Bird Distribution by Field Size

Studies indicate that farm field size is an important factor related to field selection by waterfowl and that they generally prefer larger fields (Fox 2017, Merkens et.al. 2017). Our analysis revealed positive linear correlations between average number of birds and field size for all avian groups between 2011 and 2017, with numbers of birds increasing with bigger fields (Figure 6) with the exception of Raptors for which no relationship was evident.

Studies indicate that predation risk also influences habitat use by birds (Fox 2017, Merkens et.al. 2017) with smaller fields posing a greater risk to birds than larger fields, due to the proximity to field edges, where predators tend to hide (Bradbeer 2007). Other factors, such as level of disturbance (i.e. farm traffic, hunters, etc.), and landscape features (i.e. ponds, distance from the water), need to be considered when assessing field preference by bird populations (Merkens et.al. 2017, Zellweger-Fischer 2018).

We have been able to identify potential patterns in the abundance and distribution of migratory and overwintering bird populations in relationship to some of the current agricultural practices and landscape features at Alaksen. While this preliminary analysis suggests field size at Alaksen seems to be a good indicator of bird abundance, more thorough statistical analysis could further guidance in the development of management options. A more detailed analysis could include the use of formal statistical approaches to determine probabilistic differences among crop preferences by avian group or a finer level of temporal resolution (i.e. preferences by season). This type of analysis could help identify the relative mixes or acreages

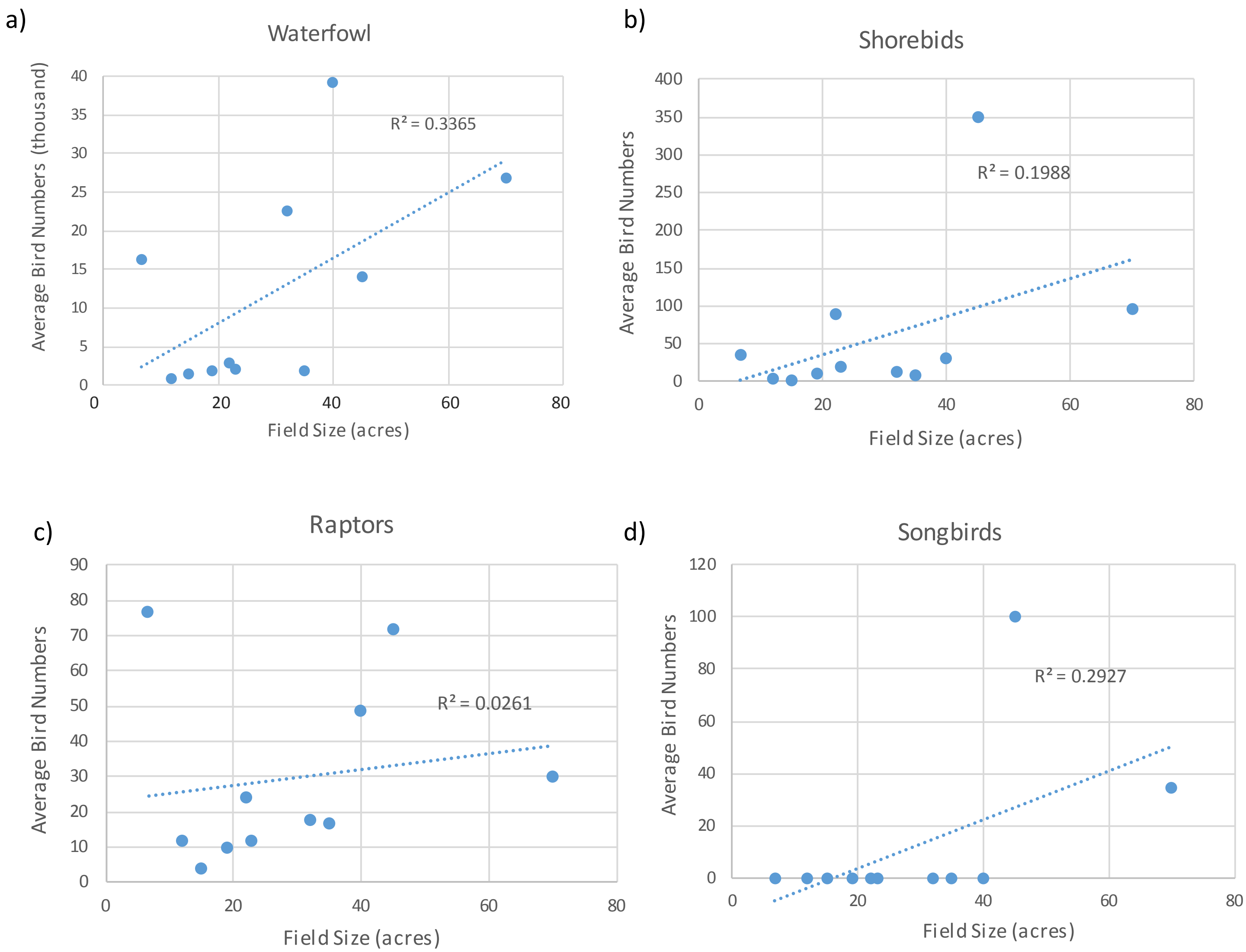

Figure 6: Average number of birds observed per year versus field size by avian group (generally October through March) per year (November 3, 2011 to February 28, 2017) for (a) waterfowl, (b) shorebirds, (c) raptors and (d) songbirds.

of particular crop types to reduce winter cover losses and maximize effective habitat. Understanding the rate of cover crop establishment and its presence over the winter months could also help assess the protected area's capacity for habitat provision. Given that avian abundance is not solely related to crop type or field size it would also be important to analyze these data within the context of other environmental factors. A multivariate statistical analysis that incorporates management, weather, field size or other environmental factors could illuminate which farmscape management practices are more likely to lead to greater bird abundance and help identify which attributes and agricultural practices are best utilized for enhancement of habitat conditions, so that some of these important resources are maintained throughout the winter. Additionally, results of such analysis could substantially inform the creation of a management plan aimed at increasing the resilience of the entire Alaksen agroecosystem.

4.3. Potential Impacts of Pesticide Use on Wildlife and Their Environment

A pesticide, per provincial legislation, is any substance or mixture of substances that are used to prevent, destroy, repel, attract or reduce pest populations (Adams 2005). Since the inception of the 'pesticide era' (beginning post- WWII), there has been a growing concern regarding the adverse effects of pesticides to human health, non-target species and the environment. Not only can acute pesticide poisoning directly result in wildlife mortality but it is also well-established that long-term exposure to low levels of pesticides can also negatively impact wildlife and wildlife habitat.

Studies conducted to assess the environmental toxicity of pesticides on wildlife are designed to measure the level of acute toxicity of their active ingredients (Adams 2005). Acute toxicity is the degree to which a chemical is poisonous as a single dose or series of doses within a short period of time (i.e. a few days) (Adams 2005). Acute toxicity to wildlife on land is expressed as a mean lethal dose (LD50), which is the amount of pesticide expressed in mg toxin/ kg body weight that kills 50% of the test population. The acute toxicity of pesticides to aquatic organisms is expressed as the median lethal concentration (LC50) of the chemical in water that will cause the death of 50% of the population of test organisms in a given time (usually 96 hours) (Adams 2005). This concentration is expressed as

Table 5: Ecological toxicity of pesticides used at Alaksen

Tradename	Birds	Mammals	Soil Organisms	Fish	Aquatic Organism	Bees	Insects	Bioaccumulation
Movento	T	T	HT	HT	HT	HT	HT	Un
Losrban	T-HT	T	Un	HT	HT	HT	HT	Un
Rival	T	T	T	T-HT	T-HT	Un	Un	**Yes**
Bravo	T	T	T	HT	HT	Un	Un	Un
Ripcord	T	T	T	HT	HT	HT	HT	Un
Closer	Un	Un	Un	Un	Un	HT	HT	Un
Cruzate	T	T	T	T	T	T	T	Un
Quadris	T	T	T	T	T	T	T	Un
Tattoo	NT	NT	T	T	T	Un	Un	Un
Gavel	T	T	T	T	Un	NT	Un	Un
Acrobat, Forum	T	T	Un	T	T	Un	Un	Un
Lorox	T		Un	HT	HT	Un	Un	Un
Sencor	T	T	Un	T	T	Un	Un	Un
Gramoxone	NT	NT	Un	T-HT	T-HT	NT		**Yes**
Malathion	T	Un	Un	HT	HT	HT	HT	**No**
Region	T	Un	Un	T	T	Un	Un	**Yes**
Dessica	T	Un	Un	T	T	Un	Un	**Yes**

NT: Non-toxic, Un: Unknown, T: Toxic, T-TH: Toxic to Highly Toxic, HT: Highly Toxic parts per million or milligrams of toxicant per liter of water. Due to effects of environmental conditions on pesticide action, LC50 test results can show large variability and consequently the test is regarded as having limited value as an indicator (Adams 2005). For any given organism, concentrations below an LC50 value might be toxic, as the "threshold of toxicity" may be considerably lower than indicated by the LC50 (Adams 2005).

Table 5 presents a list of pesticides used by Alaksen farmers and a categorization of their ecological toxicity based on peer reviewed scientific studies, and pesticide registration data (Table 1). Assessment of the relative risks of pesticides to land and aquatic environments and species requires information on toxicity, accumulation potential, and expected environmental concentrations assessed per recommended application rates and environmental conditions (Adams 2005). Studies indicate that at recommended application rates, several pesticides used in Alaksen may have high levels of ecological toxicity and long residual persistence in both terrestrial and aquatic environments (Juo et.al. 1978, National Library of Medicine 1992, Racke 1992, Rao et.al. 1980, Schimmel et.al. 1983). For example, clorpyriphos (trade name Lorsban), a broad-spectrum insecticide, is highly toxic to freshwater fish, aquatic invertebrates and estuarine and marine organisms (United States Environmental Protection Agency 1989). Studies assessing the effect of continuous exposure of fish to chlorpyriphos during the embryonic through fry stages, have shown that it accumulates in the tissues of aquatic organisms (Racke 1992). Due to its high acute toxicity and its persistence on soil sediment, chlorpyrifos may represent a hazard to sea bottom dwellers (Schimmel et.al. 1983). Paraquat (trade name Gramaxone), a herbicide widely used for broadleaf weed control, is quickly and strongly adsorbed by soil particles, especially by clays. As a result of its high propensity for adsorption, its movement through and over the soil profile is limited (Juo et.al. 1978). Because of its immobility, and its resistance to microbial degradation and breakdown by sunlight, paraquat can be active in the soil for long periods of time (Rao et.al. 1980). Its reported half-life in soil ranges from 16 months, when observed under aerobic laboratory conditions, to 13 years, observed under field conditions (Rao et.al. 1980). The bound residues that persist indefinitely in the soil are eventually transported to the aquatic environments by sediment runoff (Juo et.al. 1978). Once in the aquatic medium, paraquat is highly toxic to many species of aquatic life including rainbow trout (*Oncorhynchus mykiss*), bluegill (*Lepomis macrochirus*), and channel catfish (*Ictalurus punctatus*) (National Library of Medicine 1992).

Onsite use of pesticides may not be the only concern in regard to wildlife exposure at Alaksen. A study conducted to assess pesticide presence in Coho salmon (*Oncorhynchus kisutch*) habitat in the agricultural area of the Fraser River valley indicated that pesticide contamination is dominated by contemporarily used pesticides, such as acid-extractable herbicides, organophosphates, and triazines, but also has contaminants of legacy pesticides of the organochlorine class used from the 1950s until the 1970's (Harris et.al. 2008). Out of the eighty pesticides tested in the study, the presence of thirty-six was detected across a variety of sample types. Atrazine, a commonly used agricultural herbicide s in British Columbia, accounted for 92% of the total pesticide concentration in sediment at the study site (Harris et.al. 2008). Atrazine has been documented to be mobile in the environment (Hyer et.al. 2001), and can persist in soil for up to 18 years (Puckett et.al. 2005). The study also found indications that total pesticide concentrations tended to increase from upstream to downstream, and concentrations tended to increase from fall to spring (Harris et.al. 2008).

These results raise some important questions about irrigation methods and water availability at Alaksen, since imported water from the Fraser River entering the system of sloughs and ditches, used for the irrigation of crops has been shown to contain pesticides, and other contaminants such as heavy metals, fertilizers, and pathogens from wastewater treatment plants, industrial discharges, metal fabricating plants, sawmills, pulp and paper mills, and chemical plants (Shaw et.al. 1998).

An evaluation of water quality from the Fraser River entering the water systems of Alaksen, and how agricultural operations affects water quality could be important for the conservation or restoration of ecosystem function. Additional collection and testing of slough water, although expensive, could be used to improve conditions, and as a point of reference for water quality assessment when expansion of the Deltaport and the Massey Tunnel corridor results in changes to the current regional hydrological system. Doing so could importantly inform an agriculture management plan.

Figure 7: Grass production under two different drainage systems (field 6 and field 5) showing ponding in one system and not the other. April 2018

Figure 8: Biomass production and ground cover under two different drainage systems (field 6 and field 5) illustrating reduced establishment in the poorly drained field . April 2018

Figure 9: Soil displaying gleying characteristics (greyish-blue with reddish brown mottles due to the presence of ferrous iron in anaerobic conditions) in field 6. April 2018

Figure 10: Dead improved forage grass (yellow) and colonizing native grass (green) in poorly drained soil. April 2018.

4.4. Negative Feedbacks of Poor Drainage

Soils at Alaksen are moderately to poorly drained. Factors such as soil texture, being below the sea level, the high-water table, and high precipitation rates keep some fields soils with saturated conditions for extended periods of time. During our field observations in early spring, we noted that fields with poor drainage exhibited an overall reduction in covered soil surfaces, due perhaps to uneven seed germination, poor crop establishment, and/or crop failures during the wet seasons (Figure 8 and Figure 9). We also noticed that gleying (uniform grey, green and blue coloration of the soil) was very common in these fields. Gleying occurs when metals, such as iron, are reduced (blue-grey hue under anaerobic conditions), and re-oxidized (reddish or brown mottles) in soils that remain waterlogged for extended periods of time (Principe 2002).

Poor drainage conditions are also known to promote the upward movement of soluble salts from the lower soil profile. An increase in soil salinity and excessive soil water retention can cause crop damage and promote colonization of the fields by shallow rooted, salt tolerant plant (weed) species. Due to their poor palatability and low nutrient content, these plants are ill-suited to support the increasing populations of migration and overwintering birds (Principe 2002) (Figure 10). Additionally, poor drainage conditions may contribute to a negative feedback loop whereby saturated soils reduce plant establishment and soil organic matter with resultant increased ponding which, in turn, may attract feeding waterfowl resulting in further decrease of vegetative cover and promotion of surface sealing of the soil.

A thorough assessment and categorization of drainage conditions and an evaluation of the strategies for addressing drainage and salinity issues is necessary for the development of a plan to improve the efficacy of the drainage management/system and practices in place. A better understanding of the relationship between drainage conditions, and salt content, as well as the dynamics between crops and salt tolerant species can inform and facilitate the implementation of management practices that address the issues of waterlogging and increased salinity, with the aim to increase biomass productivity and enhance the wildlife carrying capacity of the agroecosystem.

5. Diversifying the Current Crop Selection

A significant concern expressed by Alaksen farmers during our interviews was the challenges posed by the abbreviation of the growing season over the last decade or two (presumably due to climate change impacts). Farmers noted that over the years, they have been forced to delay the establishment of summer crops due to excessively wet field conditions that extend late into the spring. This delay results in a significant contraction in the number of days to produce marketable vegetables. Consequently, operations are experiencing a decrease in yield quantity and quality. The farmers concur that it is becoming increasingly difficult to grow the crops they have traditionally grown, given this new weather pattern. These patterns are likely to persist, as climate models predict an increase in average annual temperature by 1.7ºC to 4.5ºC from 1961-1990 annual temperatures, and an increase in average annual precipitation by 4 to 17 percent from 1961-1990 levels. This increase in precipitation will mostly occur in the spring, fall and winter (BC Ministry of the Environment 2016) adversely impacting market crop establishment and harvest, and winter cover crop establishment and persistence.

A recent report by the Institute for Sustainable Food Systems (ISFS) indicate that farmers in Metro Vancouver take home less than 18% of the grocery store price of food (Sussmann et.al. 2016). For most farmers, this amount is not enough to cover costs of production. In addition, farmers in Metro Vancouver face a unique challenge with the high price of the region’s farmland. According to this report, the price range for agricultural parcels under five acres is between $150,000 to $350,000 per acre, and the price range for parcels over 40 acres is between $50,000 to $80,000 per acre. Farm Credit Canada suggests that the financial viability of many farm businesses becomes questionable when land prices approach $80,000 per acre (Farm Credit Canada 2017). Farmers at Alaksen have expressed the need to maintain their production rates to remain competitive and economically viable, in light of increasing land costs in our region, and challenging marginal rates of return. This economic dynamic has increased their desire to build economic resilience into their operations. One cost-effective method to increase farm economic performance and resilience, and an option that farmers at Alaksen have been considering, is crop diversification (Lin 2011). Studies show that crop diversification can improve farms resilience by making farming operations less (economically) susceptible to fluctuations in market and changes in consumer preferences (Lin 2011). Diversification can also facilitate adaptation to the effects of climate unpredictability and extreme events (Lin 2011). Diversification of crops however remains a challenge for conventional commodity growers in our area. In the past, crop rotations at Alaksen included a larger diversity of crops, such as legumes (i.e. peas, beans). After the 1980s, these crops were eliminated from the rotation scheme due to the loss of post-harvest and processing capacity in our region (Rice 2014). Recent consumer trends reflected in an increase in direct marketing channels, such as farmers' markets, and CSA, have opened the market to new business opportunities in the way of new crop cultivars and value added products (Sussmann et.al. 2016). Similarly, increased purveyance of locally produced foods in mainstream supermarkets reflects that same trend. The potential capacity to increase the diversity of crops and cropping methods (i.e. organic) to enhance the economic sustainability of farming operations needs to be evaluated in the context of a detailed market analysis, and an evaluation of potential distribution channels, as well as agronomic suitability.

As farmers and wildlife managers explore the potential benefits of diversifying crop production and farming methods, special attention must be placed on assessing the impacts of land change use on wildlife populations. The greatest threat to Lesser Sandhill Cranes in California, for example, is changing agricultural practices in the Central Valley, where preferred crane foraging habitats- grain fields, irrigated pastures, and grasslands- continue to decrease as orchard, vineyard, and vegetable crop production increases (Shuford et.al. 2008).

One of the major factors affecting agricultural production is consumer demand (Ranjbarshamsi 2016, Bowman et.al. 2013). Over the last decades, consumer concerns for human health, social equality, animal welfare, and environmental issues has increased consumers' interest in organic agricultural products (Ranjbarshamsi 2016). A 2017 report by the Canadian Organic Growers 2017 Consumer indicated that expenditures for organic products in Canada in 2017 was estimated to be equal to $5.4 billion, up from $3.5 billion in 2012, and the value of Canadian organic exports by year end 2017 was expected to be close to $607 million. In 2013, a BC Growers Association report found that two-thirds of consumers in this province, and over three-quarters of Vancouverites, are buying organic groceries weekly (Bowman et.al. 2013). Transitioning conventional operations to an organic production, however, can involve several economic risks, such as the potential for reduced income during the organic transition period due to a reduction in yields and higher labour and total operational costs. These risks are usually outweighed by the obtained economic and environmental benefits (Reganold 2016). A forty-year study conducted by the Rodale Institute has shown that organic systems are competitive with conventional yields after a 5-year transition period, produce yields up to 40% higher in times of drought, earn 3 to 6 times more profit for farmers (due substantially to lower production input costs), leach no toxic chemicals into waterways, use 45% less energy, and release 40% fewer carbon emissions (Rodale Institute 2018). Farms operating in Alaksen are well established operations with fields and infrastructure extending beyond the boundaries of the wildlife area, and may have the potential to strengthen their economic resilience and environmental stewardship function by transitioning to an organic production. A proper assessment of the costs and benefits involved in the transition is critical for the development of a new management plan that eliminates the use of synthetic pesticides and fertilizers from the system, restores the soil quality and aquatic ecosystems, and provides a sustaining habitat for wildlife populations at Alaksen.

There are a number of challenges involved in organic crop production that need to be considered. Pest management is one of the most significant, as Alaksen farmers will not be able to use the materials they have historically relied upon to manage arthropod, pathogen and weed pests. In view of this , there needs to be an assessment of the pest management materials allowed in organic production systems, and development of regimes for their effective utilization. Other considerations include fertility management, maintaining yield, access to labour, and maintaining cash flow (Canadian Organic Growers 2018). It is imperative producers understand the certification process, and can access the resources required to successfully navigate the system, including selection of a certifying body.

On September 1, 2018, Bill 11, the Food and Agricultural Products Classification Act came into effect. Under the new regulation all products marketed in BC as organic must be certified organic. To become certified, information (purchased inputs, non-GMO documentation, field map and history, activity log, written communications, soils and water tests, harvest records, storage records, etc.) must be recorded clearly, logically, consistently, completely, for ease retrieval and annual evaluation (Hopkins et.al. 2008). The implementation of such record keeping systems by farmers can facilitate the development and implementation of a highly effective communication system between them and the CWS wildlife managers. This system will lay the foundations for the collection and storage of important records on agricultural practices and farmscape management over time.

In summary, the implementation of more diverse crop production, alternative marketing approaches, and adoption of organic production methods could serve the dual purpose of enhancing farming operation and wildlife habitat provision at Alaksen. To this end, an economic assessment evaluating cost and benefits involved in the process, accompanied by a market analysis will help farmers and managers understand the economic and market potential and challenges of new crops and organic farming. This analysis should provide a clear understanding of the size of the market and the type of products consumers are looking for. Results of a market assessment could inform the development of operational approaches that suit the farming operations' management style, their farm plan, and their farming business objectives.

6. Key Findings and Recommendations

6.1. Key Findings

Agricultural management practices maintained at Alaksen have played an important role in maintaining wildlife habitat, conciliating human activity with the needs of wildlife populations. With the increasing loss and fragmentation of critical habitat across Southwest BC, CWS aims to develop an integrated management plan that further enhances the ecological function of its farming operations. To facilitate this process, we identified several practices that have the potential to impact habitat and associated wildlife:

The late establishment of winter cover crops in the fall, and the resulting reduction of soil cover, have the potential to impact soil quality, agricultural production and food and habitat availability for wildlife over the winter.

Accounts from Alaksen farmers and our field observations indicate that when cover crops are not properly established, most of the fields lay bare by the end of winter. Unprotected by a plant cover, the soil remains exposed to erosion over the fall and winter months. Degraded fields experience uneven seed germination, poor crop establishment, and crop failures during the growing season (Odhiambo et.al. 2012). Farmers at

Alaksen report that late season planting of cover crops is becoming more common with changes in weather patterns. This delay (and resultant poor cover crop establishment and persistence) might be contributing to the slow degradation of soils and resulting in a decreased food and habitat availability for wildlife over the winter. The impacts of delayed cover crop establishment have never been properly documented or carefully examined in the context of Alaksen, and thus remain purely anecdotal.

A number of agricultural practices, such as the selection of crops and forage harvest practices, may be important factors determining the distribution and abundance patterns of bird populations within the protected area.

Several studies indicate that field preferences by migratory bird populations is determined by a combinations of agriculture management determinants, such as crop type, field size, standing water, forage cutting practices, and sources of disturbance (Merkens et.al. 2017, Zellweger-Fischer 2018). Data collected for the 2011-2017 Winter Waterbird Surveys by CWS has never been analyzed in detail to explore relationships between agricultural practices, landscape features, and bird population abundance and distribution.

Integrated pest management practices, such as crop rotations and the use of hedgerows around fields, may be important factors when assessing the distribution and abundance of pest populations and beneficial arthropod populations within the protected area.

Although E.S. Cropconsult has monitored annual patterns of pest population fluctuations and their distribution over the last thirty years, there has never been an assessment of how some of the IPM practices or landscape attributes, such as the maintenance of hedgerows and grass margins, affect the presence and abundance of pest populations and beneficial insect populations. Assessing how IPM practices are contributing to the long-term patterns of pest and pest predators' presence and distribution, and how they can be used to predict changes in populations over time, should be examined.

The use of synthetic pesticide and other contaminants might be having a negative impact in both terrestrial and aquatic ecosystems of Alaksen.

Studies indicate that several pesticides used at Alaksen have high levels of ecological toxicity and long residence time in both terrestrial and aquatic environments (Juo et.al. 1978, National Library of Medicine 1992, Rao et.al. 1980, Racke 1992, Schimmel, et.al. 1983). Imported water from the Fraser River used for the irrigation of crops also was found to contain pesticides, and other contaminants such as heavy metals, fertilizers, and pathogens from wastewater treatment plants and other industry (Shaw et.al. 1998). Even though there has been some analysis that indicate these contaminants are present in sloughs and ditches, the extent and short and long-term effects of pesticides and other contaminant on wildlife and wildlife habitat at Alaksen have not been examined in detail.

Some of the current soil management practices at Alaksen, such as intense tillage and the inadequate establishment of winter cover crops, may be having a negative impact on soil quality, reducing agricultural production, as well as the provision of food and habitat for wildlife populations.

A number of soil related issues that are driven by intensive agricultural production (Neufield et.al. 2017, Odhiambo et.al. 2012), such as heavy tillage or working the soil under wet and dry conditions, have been linked to the degradation of soils on farms in Delta (Neufeld et.al. 2017). In addition, over the last thirty years, there has been a significant decrease in soil organic matter because of a shift from a diverse farming practice to intense vegetable production (Odhiambo et.al 2012). The impact that some of these agricultural management practices have on soil quality, and how they could potentially compromise long-term soil sustainability, have not been assessed.

Poor drainage in agricultural fields is an ongoing issue, with potential negative effects on soil quality, agricultural production, and the provision of quality habitat for wildlife populations.

During our field observations in early spring, we noted that fields with poor drainage exhibited an overall reduction in covered soil surfaces. Fields that remain flooded for long periods of time during the winter months, seems to exhibit a negative feedback loop, where saturated soils reduce plant establishment and soil organic matter, with resultant increasing ponding, which may attract more waterfowl. Increased waterfowl traffic further decrease vegetative cover and promotes surface sealing of the soil.

The shortening of growing seasons due to changes in weather patterns is making it harder for farmers to harvest their marketable crops in time, resulting in a decrease in yield quantity and quality, and delay establishment of winter cover crops.

A significant concern expressed by Alaksen farmers during our interviews was the challenges posed by the abbreviation of the growing season over the last decade or two. The significant contraction in the number of days to produce marketable vegetables and establish winter cover crops in a timely manner is causing a decrease in crop yield quantity and quality. This presents a challenge, as farmers have expressed their need to maintain yield to remain competitive and economically viable, in light of increasing land prices in our region, high costs of production, and challenging marginal rates of return.

6.2. Recommendations for Future Research

In this section, we provide recommendations for future research to inform an agricultural management plan with the goal of enhancing ecological functions of the protected area. To address the key problems identified above we recommend:

An assessment of the current winter cover crop selection and planting practices, to determine their rate of establishment, and their role in maintaining soil quality and supporting wildlife and wildlife habitat.

Improving cover crop establishment and subsequently soil cover in Alaksen could have important benefits for both wildlife and the sustainability of agricultural production. Results of the assessment will be germane regarding identification of novel cover crop cultivars and sowing practices to improve the timely establishment and subsequent provision of food and habitat for overwintering wildlife populations. Identifying cover crops that are best suited for the changing weather, cropping conditions and wildlife feeding pressure could help ensure that this important food and habitat source is maintained throughout the winter. Alternatively, there may be changes in cropping practices that could increase cover crop success.

An evaluation of how the current agronomical practices may be determining the abundance and distribution patterns of migratory and overwintering bird populations.

Given that avian distribution seems to be determined by a combination of agricultural and landscape factors, a multivariate statistical analysis could help identify which attributes and agricultural practices are best utilized for enhancement of habitat conditions, so that some of these important resources are maintained throughout the winter. Additionally, results of such analysis could substantially inform the creation of a management plan aimed at increasing the resilience of the entire Alaksen agroecosystem.

An examination of how the current integrated pest management practices may have influenced the abundance and distribution of pests and biocontrol organism populations, and their impacts over the last thirty years.

A detailed analysis of these data could help develop better models to predict pest prevalence and abundance, and improve integrated pest management practices. Additionally, future research could explore the potential economic and ecological effects of enhancing biological and cultural control (i.e. resistant cultivars) methods into farm management plans.

An evaluation of the short and long-term effects of pesticides and other contaminant on wildlife and wildlife habitat.

Understanding the impact of pesticides on wildlife habitat would identify particularly problematic pesticides in the protected area. Additionally, assessing the presence and residence time of contaminants in both terrestrial and aquatic ecosystems could help evaluate the pathways by which these contaminants have been deposited, such as agricultural runoff or off-site sources (i.e. Fraser River).

An analysis of soil quality across agricultural fields to better understand the direction and magnitude of change.

Thus far, the impacts of agricultural management practices, such as intense tillage and utilization of cover crop over the winter, on soil quality have not been studied in detail. Additional factors, such as drainage and irrigation, that could also impact the long-term sustainability of the soil, need to be evaluated.

An evaluation and categorization of drainage conditions and an evaluation of the strategies for addressing drainage and salinity issues.

This research could help develop a plan to improve the efficacy of the drainage management practices in place and determine the need for additional drainage infrastructure. A better understanding of the relationship between drainage conditions, and salt content, as well as the dynamics between crops and salt tolerant species can inform and facilitate the implementation of management practices that address the issues of waterlogging and increased salinity, with the aim to increase crop and cover-crop productivity and enhance the wildlife carrying capacity of the agroecosystem.

An agronomic and economic evaluation of potential shorter season marketable crops that could be integrated into the current rotation, that will increase yield quantity and quality, and will allow for the timely establishment of cover crops at the end of August.

Cultivars that are short season, saline and drought tolerant could be advantageous in this system. The implementation of more diverse crop production, coupled with alternative marketing approaches could serve the dual purpose of enhancing the economic viability of farming operations and wildlife habitat provision at Alaksen. Special attention should be placed on assessing how potential changes in land-use practices would impact food availability and habitat for migrating and overwintering bird populations.

Improved data collection and cataloging of agricultural practices and farmscape management could enhance the evaluation of many areas of concern and help with effective analysis of management options.

The implementation of a record keeping systems can facilitate effective communication between farmers and the CWS wildlife management. Information should be recorded clearly, logical, consistent, complete and easy to retrieve. If coupled with a strategy of simple, rapid, analysis this type of detailed record system would dramatically enhance both the farmer's and manager's capacity for adaptive management that would address the multiple objectives of the protected area. Such a system will lay the foundations for the collection and storage of important records on agricultural practices and farmscape management over time

Results of this initial assessment indicate that the overall agroecosystem integrity at Alaksen needs to be better understood. A better understanding of the system and its components can be used as the framework for the creation and implementation of a long-term management plan that considers land use change and climate change while meeting the multiple objectives of the protected area.

Protected wildlife areas in agricultural regions, such as Alaksen, are surrounded by farming operations that are driven by increased production demands. Diversified family operations are being replaced by land management companies, and contractors growing forage and livestock for large corporations (Jackson 2002). The diversity of these farming operations, with their pastures, hay meadows, grassy fence rows, hedgerows, wetlands, and riparian areas, support a diversity of wildlife and serve as corridors between wildlife habitat areas (Jackson 2002). Addressing only one aspect of a complicated human-wildlife interaction is not sufficient. Integrated planning should involve the effective management of conservation activities, while simultaneously obtaining social, environmental, and economic goals to deliver multiple benefits. A clear understanding of how agricultural production and wildlife are interacting within Alaksen is needed for the development of a collaborative framework to sustainably manage the ecosystem.

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Appendicies

APPENDIX A: Alaksen National Wildlife Area Crop Rotation Schedule and Agronomical Practices

APPENDIX B: SKAGIT NATIONAL WILDLIFE AREA: Agricultural Management Plan

APPENDIX A: Alaksen National Wildlife Area Crop Rotation Schedule and Agronomical Practices

The following set of questions were designed to fill some of the informational gaps that exists in the Crop Rotation Schedule created by CWS in 2009 and agronomic practices in place. The questionnaire is divided into five sections: cover crop, tillage and drainage, pest management, soil fertility, and irrigation. The aim of this exercise is to understand the rotation patterns of the farming operations at Alaksen, in order to explore potential agricultural practices that will further enhance the viability of farms, and build ecological and economic resilience within the system.

We truly appreciate your knowledge and input in this matter. If you have any questions, please contact Dr. Kent Mullinix at KPU (604-599-2540), or Dr. Sean Smukler at UBC (604-822-2795).

Section 1: Crop selection

1. Looking at the Cover Crop Schedule, please explain the following patterns in terms of choice of variety and their application:

   cover (fall-winter) – forage/barley (spring) – barley (fall) – forage (winter) – hay (spring) – pasture

2. What is meant, in your reports, by the terms pasture, hay, forage, cover?
3. When do you usually sow your cover crops? Late August? Early September?
4. What seeding methods are used for planting cover crops and forage (i.e. “no till” drill, land rollers, etc.)?
5. Do you apply any anti-lodging or growth regulators?
6. What is the selection of variety/s used between cash crops?
7. Are cover crops or forages incorporated into the soil?
8. Grazing takes place between May and October, what is the selection criteria for choosing fields under pasture?
9. Looking at the rotation schedule, can you recall if there were any specific field/s, or area/s within a field that needs to be periodically re-seeded? Why?
10. Can you recall if there were any specific field/s, or area/s within a field, that have the tendency to remain bare throughout the winter months? Why?
11. What are the main challenges that you face with the current crop selection?
12. What would be interested in learning about or trying that would address these challenges?
13. Are there commercial crops or cover crops that you would be interested in trying (or really don’t want to try)?

Section 2: Tillage and Drainage

14. When are fields usually tilled? What tillage methods do you use? Do certain crops get some type of consistent tillage operation?

15. What are your biggest challenges in terms of drainage?

16. What would be interested in learning about or trying that would address these challenges?

Section 3: Pest Management

17. What is your IPM plan for cover crops/forage/hay? For commercial crops? Application methods?

18. What are the primary pest (insects, disease, etc.) in the area?

19. What are the main challenges that you face with the current IPM plan?

Section 4: Soil Fertility

20. What is your soil fertility management plan for cover crops? Forage? Commercial crops? (fertilizer application dates, application rates, etc.)

21. What are the main challenges you face with the current soil fertility management plan?

22. What would be interested in learning about or trying that would address these challenges?

Section 5: Irrigation

23. Do you irrigate and if you do, when and by what method?

Thank you once again for your time and support.
Please feel free to contact me at any time if you have any questions or comments about this study.

Thank you kindly,
Grace Augustinowicz
778-316-1524
grace.augustinowicz@kpu.ca

APPENDIX B: SKAGIT NATIONAL WILDLIFE AREA: Agricultural Management Plan

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE: AGRICULTURAL LEASE

THIS LEASE is between THE WASHINGTON DEPARTMENT OF FISH AND WILDLIFE, hereinafter referred to as "WDFW" and Lessee hereinafter referred to as "THE LESSEE". WDFW grants the Lessee the right to use, in the manner prescribed herein, the agricultural lands described below located in the Johnson DeBay Slough Unit of the Skagit Wildlife Area for and in consideration of the mutual benefits to be derived. Said lands are situated in Skagit County, more particularly described as follows and in the attached Exhibit A: (outlined in red)

Legal Description: Township 34 North Range 4 East. Sections 2 and 3, Township 35 North, Range 4 East, Sections 34 and 35.

For a total of approximately 139 Acres Cropland m/l

THIS LEASE IS SUBJECT TO THE FOLLOWING MUTUALLY AGREED TERMS AND CONDITIONS:

1. TERM: The term of this lease shall occur for 3 years commencing April 1, 2017 and terminating October 31, 2019.

2. PURPOSE OF LEASE: The purpose of this lease is to produce food, cover, and habitat for wildlife. WDFW manages the land for continued multi-purpose recreation. No attempts to discourage use of the land by wildlife or the public for wildlife related recreation shall be made. Ground preparation shall not begin prior to April 1 unless an earlier starting date is discussed with and agreed upon by the Skagit Wildlife Area Manager.

3. PLANTING OF CROPS: LESSEE agrees to plant crops according to the following seed and fertilizer requirements, and planting schedule as outlined in this agreement. LESSEE is granted the exclusive right to farm the above described croplands.

   A. Corn: LESSEE will prepare the ground with a plow, disc and cultivator. The corn crop will be seeded at a rate to produce green chop with seed type recommended by Skagit Farmers Supply or Wilbur Ellis Company. The corn will be fertilized at the standard rate either with commercial fertilizer or manure. Corn must be planted by May 10 each year or weather permitting. Herbicides: Applicable herbicides and application rates will be applied by ground sprayer only. The basic recommendations is to use Roundup

   B. Barley: LESSEE will prepare the ground with a plow, disc and cultivator for planting. Barley will be seeded at a rate of 125 lbs per acre and fertilizer to be applied at 150 lbs per acre or as recommended by Skagit Farmer Supply or Wilbur Ellis. Barley must be planted before June 30 each year weather permitting. The LESSEE can also use manure application in location where this is an available option.

   C. Fava Beans: LESSEE will prepare the ground with a plow, disc and cultivator for planting. Fava Beans will be seeded at a rate of 180 lbs per acre and fertilizer to be applied at 100 lbs per acre or as recommended by Skagit Farmer Supply or Wilbur Ellis. Fava Beans must be planted before May 15 each year weather permitting. The LESSEE can also use manure application in location where this is an available option.

   D. No subleasing or sub-contracting will be allowed.

West Unit (110 acres)

A. LESSEE agrees to plant 94 acres of harvested agricultural crops …based on farm plan 2017-2019 submittal per year of the lease and maps per year (2017-2019) in Exhibit B.

B. Tilling or cuttings may begin on April 1, on each year of the lease agreement or earlier with the approval of the Skagit Wildlife Area Manager.

C. Last cuttings or harvest for inter-seeded corn or grass crops that will remain in place would occur prior to September 30 to allow over winter food resources for the swans and other waterfowl.

D. WDFW plans to rotate corn, barley and fava beans on the 22 acres within the West Unit during the term of this lease. The placement of WDFW share on the West Unit will be determined through discussion with the Skagit Wildlife Area Manager since it is understood that certain locations may be ideal for the commercial crops and this may not follow a traditional block or strip planting plan. Lessee will plant 22 acres that will be left standing (un-harvested) as part of the WDFW share outlined in Exhibit A within the agreement.

E. Lessee will plant cover crop by September 15 of each year for fully harvested crops such as spinach in order allow over winter forage resources for swans and other waterfowl to become established.

East Unit (29 acres)

A. LESSEE will plant 23 acres of corn, fava beans and barley on the North end (Field C) of the East Unit as outlined in Exhibit A, and will leave standing (un-harvested), as a part of the WDFW "share".

B. Tilling may begin on April 1, for each year of the lease agreement or earlier with the approval of the Skagit Wildlife Area Manager.

C. LESSEE may plant commercial crops on the entire South 6 acres of the East Unit each year, as outlined in Exhibit A.

4. PAYMENT/RENTAL FEES: Lessee agrees to provide ground preparations, fertilization and share crop.

    a. Each year of this lease the LESSEE will plant 45 acres of corn or fava beans and barley that will be left standing for wildlife.

    b. Payment/rental fees are based on the "fair market value" of the standing crop left for the WDFW on the East and West Units.

5. LEASEHOLD EXCISE TAX: This agreement is subject to the statues RCW 82.29, 84.36.451, and 84.40.175 which obligates lessees using public land to pay 12.84% leasehold excise tax in addition to payment of said rental fees. When a share of the crop is left in the field, and is considered as the rental fee, a 33% reduction is applied to the value of the share left for the WDFW. The statutes provide an exemption to the tax when the annual fees are less than $250.00 per year. The lessee will be billed by the WDFW at the end of each crop year. The Leasehold Excise Tax is subject to change by the Washington State Legislature.

Excise tax calculation for DeBay Slough lease.

Lease hold Excise tax will be calculated on the fair market value of the crop left standing for WDFW. This would include approximately 45 acres of corn, fava beans and barley as a part of the share crop rental agreement.

6. RESERVATION OF USE OF PREMISES BY PUBLIC: Lessee acknowledges that WDFW acquired the premises for recreational purposes and that the land shall be open at all times for lawful hunting, fishing and other recreational uses. WDFW reserves unto itself the right to make wildlife habitat developments on the premises to the extent that such developments do not reduce the cropland acreage.

7. RESTRICTIONS OF USE OF PREMISES:

   A. The lessee will permit no waste upon the premises during the term of this lease.

   B. No commercial use, unauthorized sale, or removal of any item or product from the premises will be permitted, other than products of the farming operations set forth in this lease.

   C. Livestock grazing is not permitted on the lands under this lease.

   D. The Lessee shall not expand the cropland acreage.

8. COMPLIANCE - ALL AGENCIES AND LAWS: Lessee shall comply with all applicable laws, rules and regulations, made thereunder by other agencies and government jurisdictions, in performing the work subject to this lease. No unlawful acts or activities shall be permitted on the premises by the Lessee, his agents, or licensees. All aspects of management and use of WDFW lands involved in this lease shall be under the immediate supervision of WDFW's Regional Director or his/her authorized representative.

9. ASSIGNMENT OF LEASE: This lease shall not be assigned, sublet, or transferred in any manner without written approval from WDFW.

10. HB 1309 ECOSYSTEM STANDARD: This permit is subject to and complies with HB1309 Ecosystem Standards as required on State-owned agricultural and grazing land. A copy of said document is attached and by reference hereto is made a part of this permit.

11. INDEMNITY: The Lessee shall not hold WDFW and their successors or assigns, liable for any damages or injuries caused by the Lessee's exercise of the rights herein granted and the Lessee further agrees to indemnify and hold harmless WDFW, its agents and employees on account of damages or claims of damages by whomsoever made and of any nature whatsoever arising out of or in any manner connected with the rights herein described.

12. CANCELLATION OF LEASE: The Lessee may cancel this lease at any time during the term thereof. If Lessee elects to cancel before termination, he thereby waives all rights to his interest in any monies he has invested in farming, including labor and any future USDA payments of any kind. WDFW may cancel this lease without cause at the end of any crop year during the term of this lease by written notice to the Lessee. WDFW may cancel this lease for cause at any time during the term of this lease by written notice to the Lessee. Cause for cancellation by WDFW shall be failure by the Lessee to comply with any of the terms or conditions contained herein. In the event of cancellation by WDFW for cause, all rights of the Lessee under this lease shall cease and all investment in farming performed and future crops shall be forfeited as liquidated damages, without further process. WDFW also reserves the right to cancel

this lease in the event the property as described herein is sold or traded. Should this lease be cancelled for any of the above reasons, Lessee shall release to WDFW their position in any USDA contracts or programs related to the above described property.

13. SURRENDER OF THE PERMISES: Upon cancellation or termination of this lease, Lessee agrees to immediately vacate and deliver up the premises to WDFW in a condition as good as, or better than, that which presently exists, reasonable wear and tear by the elements excepted. Any property of Lessee that remains upon the premises thirty (30) days after termination or cancellation of this lease shall become the property of WDFW without further process, or, at WDFW's option, may be removed by WDFW at Lessee's sole cost.

14. VENUE: In the event of a lawsuit involving this lease, jurisdiction and venue shall be proper only in the State of Washington, Thurston County Superior Court.

15. SEVERABILITY: If any covenant or provision of this permit shall be adjudged void, such adjudication shall not affect the validity, obligation or performance of any other covenant or provision, or part thereof, which in itself is valid if such remainder, conforms to the terms and requirements of applicable law and the intent of this lease.

16. ENTIRE AGREEMENT/INTEGRATION: This document contains the entire agreement between the parties, and no statement, promise, representation, inducement or agreement made by WDFW or its agents or employees that are not contained in this written agreement shall be valid, binding or enforceable. By signature below, the parties warrant that they have read and understood this instrument and agree to be bound by its term.

The parties hereto have executed this lease as below subscribed.

_______________ ____

Date Lessee

_______________ ____

Date Lessee

WASHINGTON DEPARTMENT OF FISH WILDLIFE

_______________ ____

Date

Cynthia Wilkerson, Lands Division Manager