

Winter Cover Crops on the Fraser River Delta: 20 Years of Greenfields

March 2012



Delta Farmland & Wildlife Trust



*"Promoting the preservation of
farmland and associated
wildlife habitat on the Fraser
delta through sustainable
farming and land stewardship"*

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Acknowledgements

This report is the culmination of over 20 years of co-operative land stewardship between local farmers and conservation organizations on the lower Fraser River delta. The "Greenfields Project" was first introduced to the farming community of Delta, BC in 1990. Since then, it has evolved into the Winter Cover Crop Stewardship Program administered by the Delta Farmland & Wildlife Trust.

Support for the Winter Cover Crop Stewardship Program has been provided by the Delta Agricultural Society, the British Columbia Waterfowl Society, Ducks Unlimited Canada, the Habitat Conservation Trust Foundation, Vancity enviroFund and the Agriculture, Environment & Wildlife Fund (Province of BC, Government of Canada, and the Investment Agriculture Foundation).

It is imperative to recognize that the farmers of Delta have been the ones planting winter cover crops for the last 20 years. Without their efforts, there would be significantly less winter feeding opportunities for migratory waterfowl. Through the work of the farming community, the soil and wildlife resources of the lower Fraser River delta are being stewarded for future generations.



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Preface

Key Points

- The lower Fraser River delta is a significant staging and wintering area for migratory birds.
- The lower Fraser River delta has fertile soils ideal for agricultural production.
- Agriculture can contribute to waterfowl conservation by providing feeding habitat.
- Development, including residential, industrial, commercial and the associated transportation corridors compete with agriculture for land use.

The Fraser River Delta is the largest estuary on Canada's Pacific coast (Butler and Campbell 1987) and located such that human and non-human interests overlap. Before European settlement the landscape of the lower floodplain was predominantly herbaceous vegetation including marsh and grassland (North et al. 1979). Since dyking and drainage in the late 1800's, there has been an increasing human presence and influence on the region. The land has value for humans and wildlife, sometimes in conflicting ways.

Agriculture currently represents approximately 41% of the land use on the lower Fraser River delta, and the majority of that area is zoned as Agricultural Land Reserve (ALR) and thus must remain as agricultural land (Agricultural Land Commission 2009, Fraser 2004). The region produces a variety of crops, including potatoes, beans, peas, corn, cole crops (cabbage, broccoli, rutabaga), other annual field vegetables, berries, perennial forage, and grain for livestock feed (Fraser 2004). The region produces a large portion of British Columbia's total potato production: 151,646 tonnes in 2009 (BC Vegetable Marketing Commission, unpublished data). Currently, the increasing urban population of the region is competing with agriculture to develop land for residential, commercial, and industrial use, as well as the associated transportation corridors.

In addition to pressure from development, agriculture on the lower Fraser River delta has a unique set of production challenges. The heavy silt/clay soils of the area require intensive tillage and are prone to degradation due to compaction, rain erosion and low soil organic matter content. Crop yields can decline as soils degrade, and farmers must continuously add organic matter to maintain ideal growing conditions (Hermawan and Bomke 1996).

The lower Fraser River delta is also a stopover and wintering area for many migratory waterfowl, raptors, songbirds and shorebirds as well as habitat for resident birds (Butler and Campbell 1987). The region hosts numerous species of waterfowl during winter, including several which often forage on agricultural fields (Butler 1992). These waterfowl species feed on harvested vegetable residue (e.g., potatoes and corn), cereal cover crops, perennial forage grass, weeds seeds, and grain.

The close juxtaposition of farming and wildlife creates challenges for the farming community. Perennial forage crops grown for livestock feed (hay, pasture, or silage) can be grazed by herbivorous waterfowl, especially Lesser Snow Geese (*Chen caerulescens c.*) and American Wigeon (*Anas americana*) (Zbeetnoff and McTavish 2004; Merkens et al. in press). Waterfowl grazing can be costly for farmers who must either forgo selling the forage crop or reseed extensively damaged fields. Frequently, the dairy farmers must purchase replacement feed for their herd when their fields are grazed by waterfowl (Zbeetnoff and McTavish 2004).

In an effort to address both challenges to soil and wildlife conservation, farmers incorporate winter cover crops into their farm planning. **A cover crop is any plant species that is used in a farming system to improve or protect soil** and, depending on the species used, can provide a wide range of agronomic and environmental benefits. On the lower Fraser River delta, cover crops are usually cereal grasses (e.g., barley or wheat) and are planted in the late summer and early fall to protect soil from rain erosion, scavenge excess nutrients from the soil, and shade out late season weeds. At the beginning of the next growing season, the roots and leaves of a cover crop can be tilled into the soil to increase organic matter. In addition to their role in soil management, cover crops can provide feeding habitat for waterfowl and potentially lure waterfowl from perennial forage fields, thus offsetting grazing damage.

The integration of winter cover crops into the cropping systems of the lower Fraser River delta can be valuable for agriculture and wildlife, and has been encouraged since the initiation of the Greenfields Project (now the Winter Cover Crop Program) in 1990. The Project began as a cooperative venture between farmers and conservationists and provided farmers with cereal grass seed for planting cover crops. In 1993 the Delta Farmland & Wildlife Trust (DF&WT) began coordinating the Winter Cover Crop Program. Through the program, Delta farmers who plant winter cover crops are eligible to receive a cost-share. Since 1990, over 57,000 acres have been planted, with an average of approximately 3,000 acres established per year.

The Winter Cover Crop Program supports the mission of DF&WT to preserve farmland and associated wildlife habitat through sustainable farming and land stewardship. It provides a financial incentive to farmers for planting winter cover crops, providing herbivorous waterfowl with a relatively protein-rich food source, and luring waterfowl away from perennial forage. The program also improves the soil by preventing erosion and increasing organic matter, thereby improving soil structure.

This report will outline the strategies that DF&WT will be adopting to ensure that the Winter Cover Crop Program continues to be an effective way of improving agricultural production and providing habitat for wildlife. In the "**Winter Cover Crops on the Fraser River Delta: 20 years of Greenfields**" a brief summary of past research is synthesized and combined with recommendations for the management of the program in future years. The reader can then refer to the various sections within this report that address specific aspects of the program including: the history of cover crops in Delta (**Section 1**); the role of winter cover crops in local crop rotations (**Section 2**); farmers' perspectives on cover crops (**Section 3**); the role of winter cover crops in wildlife management (**Section 4**); a summary of winter cover crop grazing surveys (**Section 5**); and a summary of the most recent experimental evaluation of cover crops and their ability to support migratory waterfowl (**Section 6**).

Review of DF&WT's Winter Cover Crop Program

"There can be no doubt that a society rooted in the soil is more stable than one rooted in pavements."

-Aldo Leopold

Key Points

- Cover crops provide benefits to soil and wildlife conservation.
- Cover crop type and planting date influence their value to waterfowl and to soil quality.
- Cost share rates play a role in shaping farmers' practices, and should be maintained to encourage cover cropping.
- Field trials are under way to quantify waterfowl field use.
- Continuous consultation with local farmers is essential to the success of the program.
- Agriculture faces many challenges in the future, and the DF&WT will continue to support local food production through Stewardship Programs.

Cover crops provide a myriad of benefits to both agricultural production and wildlife conservation. The recommendations presented below provide a framework for the future guidance of the Winter Cover Crop Program. With an average of 3,000 acres of winter cover crops now planted on an annual basis, it is imperative that cover crop management continues to fulfill the goals of the stewardship program, which are to:

- Maintain the soil productivity of farmland on the lower Fraser River delta by reducing soil erosion; increasing soil organic matter; and increasing soil fertility.
- Provide migratory waterfowl populations with feeding habitat between mid- fall and early spring.
- Offset grazing damage to perennial forage crops by managing cover crops as effective lures for waterfowl.

Variety is Critical for Cover Crops and Management Practices

No single cover crop is suited to fulfilling all of the goals mentioned above. This report has identified that winter cereals, especially those planted in late August and early September, support the greatest number of waterfowl (Section 6). However, they are generally grazed off by December (especially when planted later than mid-September) and provide almost no late winter/early spring soil cover (Section 5). Furthermore, winter cereals planted in late September and early October support far fewer waterfowl (Section 6). Spring cereals also tend to support few waterfowl (Section 6) but protect soils for longer, because of the winter killed mulch left on the soil surface, provide additional organic matter for spring plough-in, (Sections 2 and 5) and are less costly to establish (Section 3).

New management practices and cover crop types are always waiting to be discovered and identifying them should be a priority for DF&WT. For example, a farmer on Westham Island suggested that winter and spring cereals be planted in a mix to reap the benefits to both

waterfowl and soil fertility. It is hypothesized that the spring cereal would winter kill and provide cover for the soil, while the winter cereal will provide feed for waterfowl.

New cover crops must be integrated into existing crop rotations. Summer grain crops are an important component of the local crop rotation because they increase soil organic matter and require relatively few inputs. DF&WT and UBC researchers are investigating clover as a cover crop that can be relay cropped with summer grain crops. The benefits of clover are that it fixes nitrogen and its deep taproots break up compaction caused by machinery. Research conducted in Delta has shown that the nitrogen release profile of clover/cereal cover crop mixes is more conducive to supplying N to the subsequent cash crops when compared to single-species cereal cover crops (Odhiambo and Bomke 2000). If relay cropped with grain, the clover establishes early, providing a thick stand by fall. The farmer is able to grow clover at the same time as the grain crop, and therefore does not have to rework the soil to plant a cover crop after the grain harvest.

DF&WT is also permitting perennial forage grasses under-seeded into grain to be eligible as a cover crop. In the past, DF&WT only permitted timothy grass under-seeded into grain as a cover crop; however other perennial forage grasses like tall fescue and orchard grass are equally capable of protecting the soil from erosion, increasing organic matter, and providing feed for waterfowl. Farmers in Delta have used this practice in the past without the stewardship program, but providing a cost-share will ensure that the practice is adopted over a greater area of landscape.

New opportunities also exist with novel cultivars of winter and spring cereals. UBC researchers are currently assessing winter wheat varieties for resistance to fungal pathogens, and ability to withstand waterfowl grazing and water logging. They are also evaluating the economic value of these cultivars for livestock feed and human consumption. These new cereal varieties may provide farmers with beneficial cover crops that can double as harvestable grain crops requiring less fungicide.

Cost-share Incentives Influence Management Decisions

Farmers base their decisions about cover crops on a variety of factors, and cost of establishment is an important consideration (Section 3). Spring cereals are less expensive than winter cereals so farmers generally opt to plant these before the cut-off date (September 15). However spring cereals provide little benefit to waterfowl, so new cost-share incentives have been adopted for the 2010 stewardship program. Winter cereals planted in late summer support more birds than those planted in early fall. Therefore, DF&WT now provides greater payments for winter cereals planted before August 31 (\$55/acre) and September 30 (\$50/acre). For spring cereals, a flat rate of \$40/acre (down from \$45/acre) has been adopted.

Cost-share incentives can be managed to influence cover crop management, and it is crucial that DF&WT continues to discuss the operational costs of cover cropping with local farmers. For instance, it is important that the cost-share for spring cereals is not dropped below a threshold that would completely dissuade farmers from planting them. As previously mentioned, spring cereals are beneficial to soil management and are preferred by farmers because of lower cost of establishment and easy management in spring. Therefore, farmers should be continuously consulted to ensure that the cost-share for spring cereals is not dropped so low that planting them is unfeasible. This will ensure that as seed, labour, fuel, and

equipment costs change, the cost-share incentives are equitable and effective in encouraging desired cover crop types and management regimes.

Research and Field Trials are Necessary to Make Informed Decisions

It is known that cover crops provide feeding habitat for migratory waterfowl and that provisioning alternative feeding habitat likely reduces feeding on perennial forage grasses (Section 4). Grazing surveys conducted on fields enrolled in the stewardship program provided evidence that earlier planted cover crops (e.g., late August) may provide more feed for waterfowl, as well as greater soil cover. However, because there is a correlation between planting date and crop type (i.e., spring cereals are planted earlier than winter cereals), it has been difficult to determine how planting date alone affects waterfowl carrying capacity and soil fertility (Section 5). Furthermore, it is impossible to quantify the number of waterfowl supported by various cover crops using visual estimates of grazing alone.

The experimental study conducted during the winter of 2009 overcame these limitations, addressing both the correlation between crop type and planting date and the need for a method which effectively quantifies waterfowl use of farmland. Using fecal pellet counts, the study investigated waterfowl use of winter wheat, spring cereals, and perennial forage (Section 6). Winter wheat was planted between late August and early October, making it possible to analyze planting date as a variable (without the error caused by a correlation between crop type and planting date). It was found that a greater number of waterfowl were supported by winter cereals planted in late August and early September than those planted in late September and early October. This in turn allowed DF&WT to make informed revisions to the cost-share incentives provided through the stewardship program.

In the future, experimental trials will involve new cover crop varieties and management practices. For instance, field-scale trials in the winters of 2010 and 2011 will assess forage grasses and clovers under-seeded into summer grain crops. Using the same fecal pellet count technique employed in the 2009 study (Section 6), DF&WT will determine the relative waterfowl carrying capacity of these "new" management practices. Also, UBC researchers will investigate the value of clover to soil fertility. In conjunction with these evaluations, DF&WT will further quantify the influence of planting date on the waterfowl carrying capacity of winter and spring cereal.

Farmer Consultation Necessary When Adopting New Practices

As new practices and cover crop types are adopted, DF&WT must continue to consult cooperating farmers to identify potential challenges and opportunities. DF&WT staff should always meet with farmers in person to discuss new cover cropping practices and cost-share rates. This ensures that all cooperators are fully aware of changes to the stewardship program and can adapt their crop rotation accordingly. It cannot be stressed enough that the opinions and ideas of cooperating farmers should be solicited frequently in order to identify new management practices, challenges, and opportunities. Doing so will ensure that the Winter Cover Crop Program remains a cooperative and functional example of agroecosystem management.

Whither the Future?

It is important to recognize that it will only be possible for farmland to provide wildlife habitat in the long-term if local farming operations remain viable. Land development, uncertain land tenure, and the loss of local crop processing operations are all challenges for farming on the lower Fraser River delta. As farms become less viable in the short-term, farmers must sell land or cut components of their farm operation, usually to the detriment of long-term management.

For example, before the 1960s, livestock production was integrated into crop rotations, with many farms operating mixed dairy and vegetable production systems. The application of livestock manure maintained soil organic matter and, therefore, vegetable production. This system allowed farmers to maintain the fertility of their soils over long periods of time. Today, dairy farms and vegetable farms are separate, with producers specializing in one or the other. Some farmers still incorporate pasture for beef cattle into their crop rotation, but this may not last as beef prices in BC are at a historic low. With the disintegration of livestock and vegetable production, it is more difficult to manage soil fertility in vegetable operations and dairy operations are challenged to accommodate the manure they produce. As the short-term monetary returns of farming on the lower Fraser River delta decline, farmers will continue to make decisions that impact the long-term viability of local agriculture.

In the face of these challenges, the value of local farming operations to the broader community must be recognized. No other industry within our economy, except forestry and fisheries, can be managed to produce essential products for human consumption while contributing to the conservation of biodiversity. Since wetlands and marshes have been lost across the region, the future fate of our migratory waterfowl populations, as well as other wildlife species, is intimately linked to the fate of agriculture.

Besides being important to biodiversity, agriculture is inextricably linked to our economy and social framework. Farming has the potential to remain an important, long-term component of the economy because of its essentiality. It is also an integral component of rural heritage and represents a potential to increase community cohesion by bringing together a wide range of stakeholders, both rural and urban, who share a dependence on agriculture for food. However, farming can only remain a long-term contributor to our economy and communities if it is safeguarded in the short-term.

Our communities will always demand food. The question to be asked is: how will the supply of food change over time? Currently in British Columbia we source our food from an expansive global food system. But how will the global food systems of the future manifest in the face of an increasing human population, the loss of farmland to development, top soil degradation/erosion, drought, soil salinisation, rising fossil fuel prices (which impacts fertilizer prices, equipment operation and transportation costs), and economic instability? These are challenges that are not only manifesting on the lower Fraser River delta, but across the world.

In the face of this uncertainty, DF&WT will continue to support farmers on the lower Fraser River delta by providing cost-shares for the non-market environmental goods and services they provide, including migratory bird habitat, pollinator habitat, and the long-term management of our provinces most valuable soil resources. These cost-shares will continue to be provided through the Winter Cover Crop Program, as well as the Grassland Set-aside, Hedgerow, and Grass Margin Stewardship Programs. If the goal of society is to maintain food

production and conserve biodiversity, it will need to develop mechanisms that not only support local agriculture, but ones that encourage environmental stewardship.

How these mechanisms should work is unclear. The DF&WT has a role to play, but its stewardship programs alone are not enough. Perhaps government must increase support for agriculture, such as investing in the recruitment of young farmers, reducing rent on agricultural land, and aiding the development of new farm management practices and food markets. Another option is to encourage consumers to support farms that provide extensive, measurable environmental goods and services. Whatever the mechanism is, more action must be taken quickly to safeguard local agriculture for future generations.

Section 1: Cover Crops in Delta: 1990 to Present

Key Points

- The majority of the winter cover crops planted in Delta are cereal grasses.
- Spring cereals (e.g. oats and barley) are frost-sensitive and winter-killed, while winter cereals (e.g., winter wheat and fall rye) are frost-tolerant.
- Frost-sensitive spring cereals (barley, oats) tend to be planted earliest (mid-August to mid-September).
 - They are easier to manage in the spring because they winter-kill, usually by mid-December.
 - They do not provide feed for waterfowl once the vegetation has winter-killed.
- Frost-tolerant winter cereals tend to be planted from mid-September to the beginning of October.
 - Later planting means that winter cereals do not accumulate as much biomass as earlier planted spring cereals before waterfowl feeding begins.
 - Winter cereals are frost tolerant and can provide feed for waterfowl into spring, but tend to be completely grazed by mid-winter.
- Cover crop planting date is strongly influenced by cash crop harvest date.
- The type of cover crop that farmers use is influenced by seed cost and DF&WT program guidelines.

On the lower Fraser River delta, a variety of cover crops are planted, including legumes, forage grasses and cereal grasses; the majority of cover crops are cereals. The preferred cereal cover crops are either frost-sensitive spring cereals like oats and barley, winter cereals like fall rye and winter wheat, or spring cereals that are cold tolerant such as spring wheat (Temple and Bomke 2001). Since 1990 over 57,000 acres of cover crop have been planted, with peaks in 1993 and 2002 (Figure 1). On average 1,220 ha (3,000 acres) have been planted to winter cover crops per year, with a relative increase in barley over the last ten years and a relative decrease in winter wheat.

Winter-hardiness is the key difference between the frost-sensitive and frost-tolerant cover crops, which has implications for wildlife and soil management. The frost sensitive spring cereals are winter-killed in temperatures below freezing and thus only available as food for waterfowl in the late fall. Detritus from frost-killed spring cereals maintains soil cover throughout the winter and spring, and dead plant material is easy to incorporate in the spring. In contrast, winter cereals are not winter-killed and thus may be useful as waterfowl food throughout the winter and spring.

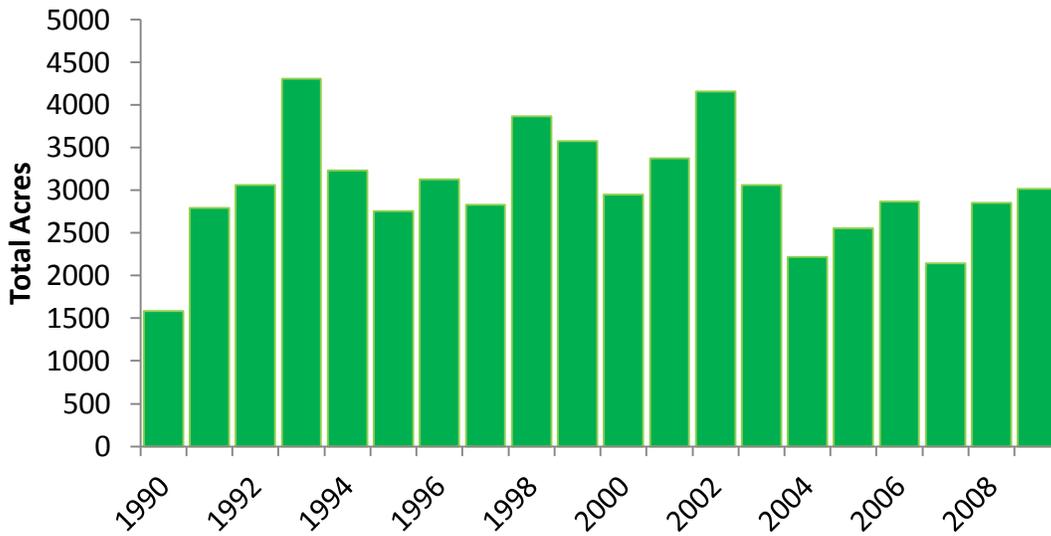


Figure 1. Total acres in Delta planted with winter cover crops from 1990 to 2009.

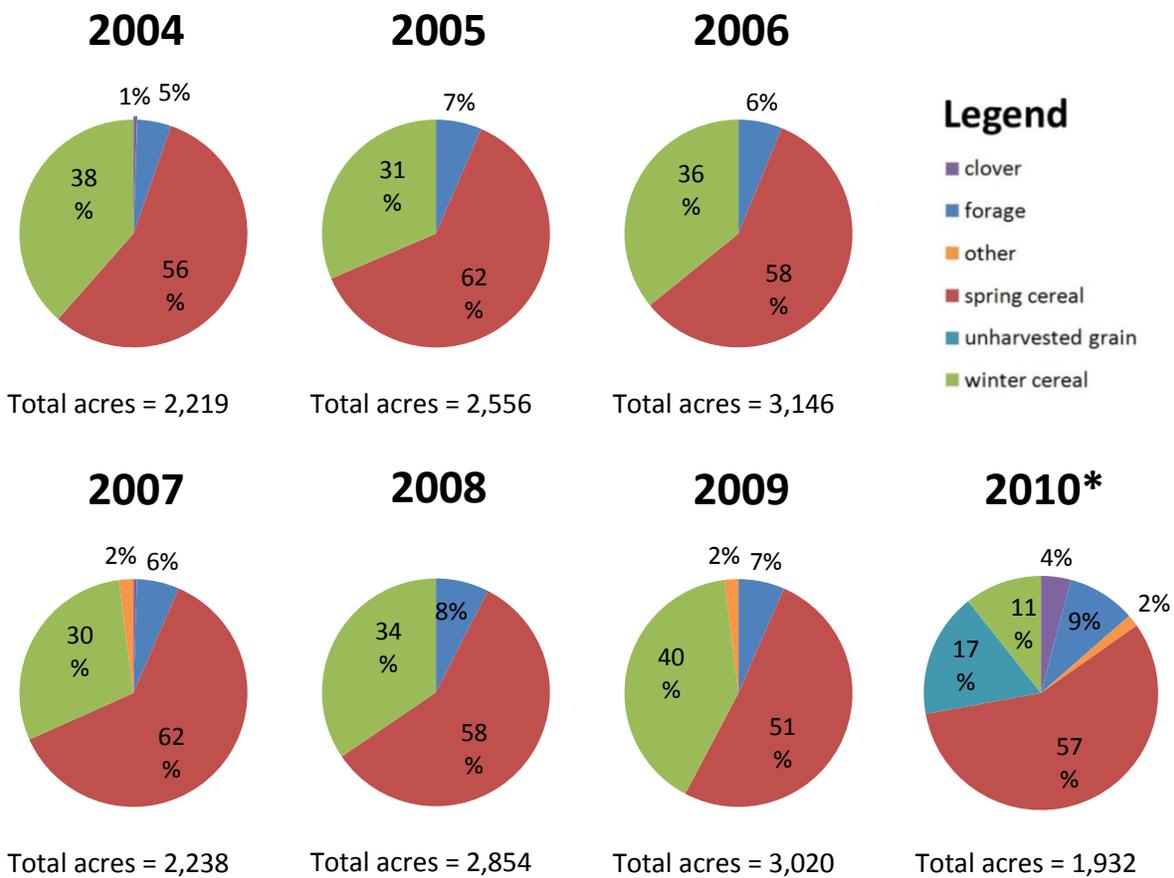


Figure 2. Proportion of different cover crop species enrolled in the Winter Cover Crop Stewardship Program, 2004-2009.

* Due to an extraordinarily wet fall in 2010, many crops were not harvested and fewer cover crops were planted, resulting in an atypical cover crop distribution.

The most common cover crop varieties are barley and winter wheat, which together accounted for over 87% of the crop area in 2000-2009. Figure 2 shows the proportion of different cover crops planted between 2004 and 2009, including the absolute acreage of cover crops planted annually. Spring cereals (including barley and oats) account for between 50 to 60% of total acres of cover crops planted, while winter cereals (primarily winter wheat but also fall rye) account for between 30 to 40% of the total acreage. Forage grasses such as annual ryegrass and Timothy, comprise between 5 to 7% of the total acreage planted.

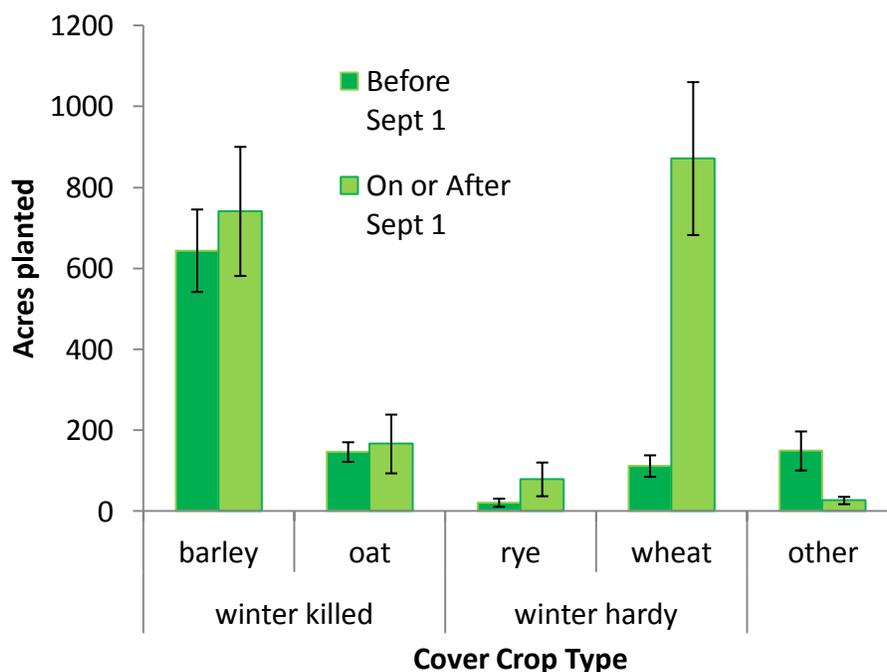


Figure 3. Average area in Delta planted with barley, oat, rye, wheat, and other cover crops from 2000-2009, with 95% confidence intervals. Each crop was divided into the area planted before September 1 and on or after September 1. Winter wheat and spring wheat were both included in “wheat” because the data did not distinguish between the two in some years, and both are frost-tolerant and can be managed similarly.

The planting date of cover crops is most often determined by the harvest date of the cash crop and DF&WT program guidelines. Farmers often plant spring cereal cover crops like oats and barley earlier in the season (before September 1). Spring cereals must be planted by September 15; otherwise they are ineligible for a cost-share. After September 1, farmers are more likely to plant winter-hardy cover crops such as winter wheat and fall rye (Figure 3). Planting cover crops early (e.g., end of August and early September) results in greater amounts of cover crop biomass. Cover crops planted in late September and early October have less time

to mature and consequently provide less soil cover and have less developed root structures, though they may be more attractive to waterfowl. Herbivorous waterfowl must consume vegetation that is high in protein and relatively low in structural fibers (Sedinger 1997) and cereal grasses contain more protein and less fiber when young.

Other than the cereal grasses, which accounted for approximately 95% of the cover crop area from 2000-2009, cover crops used include annual ryegrass, Timothy grass and other mixed forage grasses, and clover. Prior to 2000, winter triticale, forage rape, forage kale, Sudan grass, Austrian winter peas and buckwheat were also planted in cover crop trials (Temple and Bomke 2001). Many of these cover crop species established poorly during the study and were not investigated further.

The DF&WT provides a cost share to farmers who plant cover crops based on acreage and planting date. Before 2008, farmers received a flat rate for cover crops of \$45/acre. In 2008, the rate was raised to \$55 per acre for cover crops planted before August 31, and \$50 per acre for cover crops planted until October 9. Due to funding constraints in 2009, the rates were dropped to \$50 per acre for cover crops planted before August 31, and \$45 per acre for winter cereals planted until October 9. Spring cereal cover crops planted after September 15 were not eligible for funding. These rates have been adjusted in the hopes that farmers will alter their planting practices to support more waterfowl.

Section 2: Winter Cover Crop and Delta Crop Rotations

Key Points

- The soils of the lower Fraser Delta present many management challenges to farmers including low organic matter content, poor drainage, and compaction and salinity.
- Cover crops can promote agricultural production by:
 - Reducing soil erosion caused by heavy rains.
 - Increasing soil organic matter, which improves soil structure, drainage, and nutrient retention.
 - Scavenging residual soil nutrients in the late summer and early fall.
 - Suppressing weeds by shading or allelopathic chemicals.
- Cover crops can also present management challenges to farmers, including:
 - Delaying access to fields in the spring due to retained soil moisture.
 - Adding extra costs of production.
 - Providing an alternate host for crop pests.
 - Increasing difficulties in managing soil nitrogen due to varying carbon:nitrogen (C:N) ratio of cover crop vegetation.

The soils of the Fraser River delta are derived from sedimentation, with some moderately-fine textured clay soils and mostly medium-textured silt soils (Luttermerding 1981, Bertrand et al. 1991). The dominant Soil Management Groups are Delta, Crescent, Westham, Ladner, Bensen, Guichon and Spetifore (Luttmerding 1980, Luttermerding 1981, Bertrand et al. 1991), which can be agriculturally productive for crops such as potatoes, cereals, vegetables, berries, and perennial forage (Bertrand et al. 1991). The main limit to agricultural productivity across all management groups is poor drainage, and in some areas salinity, dense subsoil, high clay content, and low organic matter.

Poorly drained, waterlogged fields can result in reduced plant growth. Wet soils also prohibit tillage, planting, and prevent harvest in the fall because wet soils are more prone to surface and subsurface compaction. Low levels of organic matter make soils even more vulnerable to compaction and degradation (Bertrand et al. 1991). Compaction limits plant root growth and drainage, and high clay content in addition to low organic matter make some soils particularly sensitive to compaction (Bertrand et al. 1991). Heavy winter rains can cause the erosion of fine soil particles and the associated organic matter, thereby exacerbating soil degradation. According to Hermawan and Bomke (1997), one in three farms in the Fraser River delta has problems with their soil's structure and organic matter content. In light of these soil conditions, cover crops can ameliorate several of these limitations at once, by increasing drainage capability, breaking up dense subsoil, and increasing organic matter content. Therefore, winter cover crops play a role in managing the soils of the lower Fraser River delta.

Erosion Control

Delta has a temperate marine climate, with rain throughout the year but especially in the winter months. Approximately 70% falls in the months of October to March. Much of the precipitation occurs when the soil is bare after annual cash crops (such as potatoes and

vegetables) have been harvested. Without a cover crop the soil would be bare during the time of highest rainfall, leaving the soil vulnerable to rain erosion. Cover crops provide a physical barrier to the rain drop impact and so prevent rain splash erosion (Clark 2007).

Cover crops also prevent the loss of surface porosity and enable soil to hold more water and drain better due to the increased organic matter and improved soil structure, thereby further reducing erosion from surface runoff (Temple and Bomke 2001). Cereal cover crops can also be effective at reducing wind erosion (Snapp et al. 2005).

Soil Structure Improvements

Cover crops are an effective way to improve soil structure. Soil structure refers to the presence of soil aggregates, soil particles that are bound together by cementing agents (Bertrand et al. 1991). Good soil structure, indicated by the presence of stable granular aggregates, in a finer textured soil enables better drainage and increased aeration of the root zone. Soil structure can have a large impact upon crop yield and is influenced by management methods (Bertrand et al. 1991). Soil biota consume organic matter and produce substances which promote soil aggregation, so the amount of organic matter influences soil structure. Earthworms, for instance, leave channels in the soil that increase drainage and their casts bind soil particles into soil aggregates (Lee and Foster 1991).

Hermawan and Bomke (1997) investigated mean weight diameter, an indicator of soil structure, under spring barley, fall rye, and annual ryegrass cover crops compared to the bare control on the lower Fraser River delta. They found that mean weight diameter was greater under the cover crops, indicating improved soil structure, and that after tillage the soil had fewer clods, also a favorable outcome for soil management (Hermawan & Bomke 1997). Another study of local soils found that cover crops increased soil aggregate stability, and suggested that polysaccharides in the soil derived from root exudates, crop residues and soil microorganisms are the most important soil-binding agents in short-term aggregate improvements (Liu et al. 2005).

According to Clark (2007), the extensive root system of rye enhances drainage; the growth of plant roots, especially grass, contributes to soil aggregate formation by physically pushing soil particles closer together when roots expand, and by extracting water from top soil and causing soil mass to break and crack (Bertrand et al. 1991). Grasses can also relieve compaction through the penetrating action of their roots (Clark 2007).

Nutrient Availability

Organic matter can increase cation exchange capacity, which influences the ability of plants to take up nutrients. According to Magdoff and Weil (2004), the soil organic matter is the main source of important plant nutrients including nitrogen, phosphorous, and sulfur. Their study found that even when ample inorganic N fertilizer is applied it accounts for only 10 to 50 percent of the nitrogen taken up by heavy-feeding crops like corn (Omay et al. 1998 and Reddy & Reddy 1993 as cited in Magdoff and Weil 2004).

Grasses and other non-leguminous cover crops add organic matter but won't release nutrients very rapidly, so nutrients may be immobilized (Clark 2007). Nitrogen is a critical plant nutrient which cycles through the soil, atmosphere, and living and dead biomass in different chemical forms; the nitrogen present in the soil is not always available to plants. Odhiambo and

Bomke (2000) conducted research on the nitrogen availability following cover crops on lower Fraser River delta soils. They found that for the first eight weeks after tilling in cereal cover crops, nitrogen availability is low. However a cereal and legume cover crop mix released nitrogen sooner after tillage, which synchronized with the cash crop's nutrient needs (Odhiambo & Bomke 2000). Their study found that nitrogen mineralization, the process that makes nitrogen available to plants, occurred when the C:N ratio of plant residues was below 30:1. This highlights the importance of managing winter cover crop residue effectively. A study of grass/legume mix cover crops by Odhiambo and Bomke (2000) found that mixes such as winter wheat & crimson clover, fall rye & crimson clover, and winter wheat & hairy vetch result in nitrogen release patterns more suitable for crop growth. Therefore multi-species mixes are a potential future direction of the winter cover crop program.

Nafuma (1998) found that planting date (and therefore, overall cover crop growth) affected the C:N ratio of the cover crop in spring on farms in Delta. Remember that a ratio of less than 30:1 is ideal to release nitrogen in a form usable to plants. Generally the early planted spring cereals—barley and oats—have C:N ratios higher than 30:1 in the spring, whereas winter cereals—winter wheat and fall rye —have C:N ratios less than 30:1 (Nafuma 1998). The later the spring cereal is planted, the lower the C:N ratio is (Nafuma 1998). The implications of this research are that the later planted spring and winter cereals (early to mid September) release the nitrogen in synchrony with crop needs in the summer, whereas earlier planted (mid August) spring cereals do not (Nafuma 1998).

It is difficult to determine which cover crop type contributes more organic matter to the soil. In April the above-ground biomass of winter-hardy cereals is more than double that of winter-killed cover crops due to their spring growth (Nafuma 1998). However, it is difficult to determine which cover crop type contributes more organic matter to the soil because root biomass also contributes to organic matter, winter-killed detritus may be partially decomposed on the soil surface and the spring growth of winter-hardy cereals could be grazed by waterfowl and thus lost from the system.

Nutrient scavenging is an additional benefit provided by cover crops. In a bare field virtually all nitrate (NO_3) is lost to leaching because of the high rainfall during the winter; cover crops such as winter wheat are effective at capturing residual nitrogen in the soil, thus preventing loss from the system (Bomke et al. 1994). If properly managed, these nutrients can fertilize plant growth in subsequent years (Clark 2007).

Weed Control

Cover crops can also decrease the need for herbicides because they can successfully compete with weeds for sunlight, moisture, and nutrients. Cover crops can also produce allelopathic chemicals from root exudates and via decomposing plant material. Allelochemicals are compounds produced by plants that inhibit the growth of other plants. According to Weston (1996), allelochemicals are present in nearly all plants; their ability to influence the growth of other plants is dependent upon what chemicals are produced and on environmental conditions. Varieties of barley, triticale and rye contain compounds that have an inhibitory effect on barnyard grass and bristly foxtail without inhibiting corn growth (Dhima et al. 2006). Thus there is a potential for allelopathic chemical weed reduction using cover crops in Delta, although research is required to investigate their release and potency.

Potential Disadvantages

Although the agronomic advantages of cover cropping are numerous, it is important to point out that there are also disadvantages. The disadvantages to the farmer include the need for additional labour to plant the cover crop, labour to manage the crop in the spring, slowed soil warming (Snapp et al. 2005), delayed planting in the spring because of soil moisture retention, and potentially slowed nutrient bioavailability to the subsequent cash crop. A study conducted in Delta (Krzic et al. 2001) showed that cover crop biomass can significantly reduce soil temperature and increase soil water content in the spring, which can delay field operations. A local study of nitrogen immobilization and release patterns (Odhiambo and Bomke 2000) found that cereal cover crop residues release nitrogen at a rate that does not correspond to subsequent crop needs, whereas legume or legume-cereal mix cover crops release nitrogen in synchrony with crop needs. Incorporating legumes into cover crop seed mixes or other seed mixes are a potential future direction for cover crops in Delta. Soil improvements are not always easy to see on a year to year basis. A thorough review of the costs and benefits of winter cover cropping according to local farmers can be found in "**Section 3: Farmers Perspectives: Operational Opportunities and Challenges of Cover Crops in Delta**".

Section 3: Farmers Perspectives: Operational Opportunities and Challenges of Cover Crops in Delta

Key Points

- The Winter Cover Crop Program has increased the acreage of cover crops that are planted annually in Delta.
- Cover crops can double as winter grain crops and spring forage.
- The date of cash crop harvest is one of the most important factors influencing cover crop planting date.
- Farmers perceive that benefits to their soil from cover crops are long-term.
- Cover crop vegetation and residue can retain soil moisture in spring and delay cash crop planting.
- Spring cereals are generally preferred because they winter kill and can be easier to manage in the spring.
- Waterfowl grazing is variable and farmers perceive that cover crops can alleviate some grazing damage to perennial forage fields.

Current Perspectives

In the summer of 2009, fifteen farmers who participated in the Winter Cover Crop Program were interviewed. They were asked sixteen questions about their preferred practices, their opinions about the value of the winter cover crop program, and their outlook for costs and benefits of the program (see Appendix 2 for survey questions). Their answers were noted, and are summarized as follows.

Generally, farmers were pleased with the work done by the Delta Farmland & Wildlife Trust and believe that the Winter Cover Crop Program encourages best management practices. A few growers also mentioned that DF&WT has been incredibly useful in improving relationships between agriculturalists and environmentalists. While many farmers planted cover crops before the program existed, most planted more acreage because of the Winter Cover Crop Program. They were also more likely to plant cover crops even if waterfowl feeding will likely decrease benefit to the soil.

Interviewed farmers recognized that the main agricultural value of cover cropping is increased organic matter within a field. Other benefits include improved soil structure, nutrient retention, weed suppression, and reduced compaction and erosion. A well developed root structure was noted to be especially valuable for increasing water drainage, reducing erosion, and adding organic matter to the soil, even when the tops of the plant were grazed off completely. While some noticed improvement in cover cropped fields compared to fields which have not been cover cropped, most farmers simply knew that the cover crop benefitted their soil even if they could not see significant soil quality improvement. Some growers noted that soil quality development is a long term process which cannot be measured on a yearly basis, and some farmers felt that research would be necessary to accurately measure increased soil quality. Also, the variation in grazing pressure, crop growth, and weather cause changes in the value added by cover crops. All farmers stated that the earlier a cover crop is planted, the

greater the soil quality improvement will be. While earlier planted crops are best from an agricultural perspective and support more birds, waterfowl still prefer later planted crops.

Planting practices vary between farmers. Half of the growers prefer to broadcast seed because it is a faster, easier, and less expensive method of planting cover crops. A few drill seed because seeds attain the soil moisture required sooner and therefore grow faster, and may also produce a more even crop. One disadvantage of drilling is that seed must be clean enough (i.e., free of vegetation) to avoid clogging the operating equipment. Most farmers felt that there is little difference between drilling and broadcasting as long as sufficient moisture is available in the soil. Thus some vary planting depending upon time of year and weather. For example, one farmer stated he would use a drill before the first week of September so seeds reach moist soil, but after that date or once there has been some rain, he would broadcast because there is sufficient soil moisture closer to the soil surface.

The most important factor determining the planting date of cover crops is the date when a cash crop is harvested. This can be earlier for people with beans, peas, or strawberries, but later for people with potatoes or corn. Cover crops are usually planted as soon as possible after a field is cleared.

Seeding rates for cereal grasses vary between 110-150lbs/acre but each farmer typically works within a much smaller range. Some growers found lighter seeding rates provide sufficient growth, some consider the price of seed, and one farmer used a greater volume of seed to ensure that the heavier, thicker mass of cover crop suffocates weeds. Before the beginning of the Winter Cover Crop Program some farmers planted cereal cover crops, but at lower rates than those currently recommended by the program. For instance, one farm used to plant fall rye at 30lbs/acre, whereas the current recommended rate is between 120-135 lbs/acre. Farmers who relay crop corn fields with annual ryegrass use a very low seeding rate (30 lbs/acre) and seem to end up with a sufficiently thick cover crop. Some farmers grew their own cover crop seed and most purchased seed from another local farm.

Seed cleaning is a mechanical process which removes weed seeds or other unwanted plant material from a crop seed mix. Whether the seed has been cleaned is not a major concern because seed is most often purchased from a neighbour, so a farmer knows what the field where their seed is coming from looks like, or trusts his or her supplier. Thus, many farmers stated that un-cleaned seed is acceptable as long as they know it contained no weeds. If they did not find local seed clean enough, some farmers were willing to pay extra for cleaned seed. One farmer mentioned that cleanliness of seed is not as important for cover cropping because the field will not be harvested. Certification of seed is viewed as unnecessary and expensive; the only reason a farmer would buy certified seed would be if that was all that was available.

Growers were also asked which specific cover crops they felt were best for soil conservation and which were most preferable to waterfowl. Barley and fall rye were most commonly listed as the best for enhancing soil quality because of their biomass accumulation. Fall rye can overwinter which means it produces a large amount of biomass in the spring. For this reason production is delayed in the spring compared to a barley cover crop or a bare field. Barley produces biomass which is less attractive to waterfowl than other crops, and the decreased feeding pressure results in more organic matter going to the soil. Some farmers also listed oats, wheat, and grasses as beneficial crops for soil conservation. Most farmers believed that wheat is most heavily grazed or preferred by birds though fall rye and barley were also

mentioned as good feed. Many farmers also noted that birds consume any crop planted late because it is shorter and more tender, and as time passes they will consume anything they can. Farmers often preferred planting barley early in the fall so the crop is mature enough to withstand grazing pressure and will thereby maximize soil conservation.

All farmers surveyed believed that the Winter Cover Crop Program encourages sustainable agricultural practices. Even farmers with production which does not lend itself to cover cropping appreciated the value of the program. One dairy farmer noted that cover cropped fields can reduce pressure on forage fields. Some farmers found that the program helps keep them on track of when cover crops should be planted. Yet others wondered if planting cover crops is simply encouraging more birds to inhabit the Delta area.

There are a few main factors which affect whether or not farmers plant cover crops. Timing, crop rotation, and weather were the three most important elements considered by farmers. Although there is usually enough seed produced locally, farmers may be ready to plant cover crops before grain is harvested and available, and non-local seed can be quite a bit more expensive. Some farmers take high prices of fuel and general costs of production into consideration when deciding whether or not to plant a cover crop. Weather can affect both the stage of growth of cash crops and the ability to physically work a field. Wet weather in the fall pressures farmers to harvest cash crops within a narrow window of time, so there is not always enough time left for planting a cover crop. Also, some farmers lack the man power and cannot afford to lose staff to planting cover crops when they are busy harvesting. In addition, some farmers do not choose to plant cover crops after a late crop because they do not feel there is enough agricultural benefit.

One of the major concerns farmers have with cover crops is that they often cause a one to two week delay for planting cash crops in the spring. Because of this delay, some farmers stated they would not plant a cover crop in a field which would grow potatoes the following year. One organic grower explained that some of his cash crop seeds or transplants are planted early in the spring and require a field to be clean of debris, so he wouldn't want a cover crop in the field. The field needs to be clean because of the crop type and delicate planting machinery. Seed potato growers have further concerns with planting cover crops following a potato harvest. Since birds do not eat all the unharvested potatoes in a field if it has a cover crop in it, the left over potatoes can become volunteers and foreign among seed potatoes the following year, thus reducing the grade of the seed potatoes.

Most farmers noted a number of factors which affect the overwintering survival of a cover crop, with location as one factor. Certain areas of Delta are more heavily grazed than others; the greatest amount of damage tends to occur on Westham Island and on fields close to dykes. The drainage of a field is another factor which affects survival of a crop, because birds are attracted to standing water in low areas. Not only are birds attracted to these areas, but they further the problem by removing vegetation and compacting soil, thereby causing puddling. Finally, and possibly most importantly, primary establishment of a crop will affect its ability to withstand waterfowl grazing. The younger a cover cropped field is, the more tender it is and the more likely waterfowl are to come in and graze it.

Some farmers experienced economic losses due to waterfowl grazing and some cash crops simply cannot be grown in the area because of grazing severity. Many growers noted that grazing greatly affects forage fields either by reducing harvest volume or by forcing the use of

less favourable grass varieties. A couple of dairy farmers stated that they now have to grow fescue or canary grass because orchard grass, clover, and ryegrass are too attractive to waterfowl. Having to switch varieties creates an extra expense for these producers because they must somehow replace the protein which is lost from the grass. One farmer explained that if a field was left to be cut in May, grazing could cause a loss of about sixty bales of hay/acre which is a loss of \$300-420, when bales cost \$5-7. Sometimes an entire first cut of hay is lost to waterfowl grazing damage. Because of the significant losses which can occur in forage fields, a number of growers expressed some desire for a program which would help compensate this loss, as waterfowl are clearly benefiting from the use of these fields.

Some cover crops could overwinter and be used as an additional cash crop if they were not so heavily grazed in the winter. Farmers mentioned that cauliflower is no longer planted across Delta due to overgrazing by waterfowl, and sugar beets, though once prosperous throughout Delta, have also not been planted as much since the closure of the processing plant in the early 1950's. The existing pressure from birds is too high to consider growing sugar beets in any case. Canada Geese (*Branta canadensis*) that arrive in late August may eat beans before harvest, causing problems for some growers. One farmer experienced such a loss in May 2010, when only one fifth of his bean field survived grazing by Canadian geese. This farmer also expressed some concern about disease from droppings when birds are among directly exposed crops such as beans. In addition to increasing the risk of disease, bird droppings can be a source of weed seeds. Lastly, birds can cause compaction and puddling in a field which will affect the growth of subsequent cash crops.

While some farmers did not find that cover crops negatively affect subsequent cash crops, most had serious concern with the delay caused by cover crops in the spring. Some found extra tillage is required in the spring but the greatest cause of delay comes from retained soil moisture. The delay can also be greater for organic growers who are not able to use glyphosate herbicide to control spring growth. Cover crops can affect potatoes by attracting click beetles whose larvae (wireworms) are a major potato pest. Some farmers also found that weeds are not always choked out by cover crops so they would prefer to work a field later in the fall or earlier in the spring to remove weeds.

From an agricultural standpoint, most farmers felt that October is late to be planting cover crops. The majority of growers found that later planted cover crops become feed for waterfowl so there is a benefit to wildlife but little biomass is left to improve soil. One farmer stated that there isn't even that much biomass for the birds when crops are planted in October. Many felt that the deadline set by DF&WT is acceptable and reasonable. Others believed the date could be moved ahead to the middle or end of September. Almost all farmers stated that the deadline should be gauged depending on the weather as this plays a crucial role in the establishment and survival of a crop.

The Laser Leveling Program was highly regarded by growers in Delta. Most have leveled at least some, if not all of their fields and found that improved drainage reduces grazing damage. Most farmers found that the Grassland Set-aside Program benefits other wildlife but does not help a lot with waterfowl grazing. However a few noted that Set-asides are extensively used in certain areas, they improve soil structure, and they are very useful for transitioning from conventional to organic production. A few farmers stated that grassland set-asides would have better root structure if they were allowed to be cut, and that way the grower could get a

cash crop off and the waterfowl would be more likely to use the fields because re-growth of grass would be short and tender. One grower mentioned that grassland set-asides cause increased pressure on surrounding forage fields because waterfowl could be using those fields, had they been planted with a different crop. Besides these two programs, some farmers mentioned that they like the Liming Program offered by DF&WT.

Since the establishment of the Greenfields Project, about half of the farmers have changed their practices. Many of the farmers who have not changed their practices have always had cover crops. A few simply do not cover crop because it is not compatible with what they grow. Others who have cover cropped since before the program were likely to plant more acreage because of the financial support from DF&WT. A few growers mentioned that they would be more likely to plant late, knowing that the crop would not provide much benefit to soil, because their costs would at least be mostly covered by the program. A few growers never used to cover crop at all and now plant many acres with the support of DF&WT.

Cover cropping was not recognized by many farmers as having a direct economic benefit. Only two farmers said they had a direct economic benefit from cover crops. One said that about \$5 from the money provided by DF&WT would be left over as a direct economic benefit, and the other was a dairy farmer harvesting relay planted cover crops. Most growers felt that it was difficult to directly measure the benefit provided by cover crops. However, most noted that cover crops provide organic matter, increase nutrients, reduce lumps in soil, and greatly improve soil structure. One mentioned that legume cover crops could provide a direct financial benefit because less fertilizer would be required on these fields. A grower also mentioned that bluegrass, a weed in his field, may possibly provide organic matter equivalent to cover crops. Improved soil structure may reduce the energy required to work soil because the ground will be softer and slightly less fertilizer may be required on a field which has had cover crops. Once again though, these energy- and money-saving benefits are slight and are probably only measurable on a long term basis. Similarly, most farmers stated that they would not notice an immediate extra expense if cover crops were not planted but that problems would eventually occur if soil was continuously depleted of nutrients and organic matter. The majority of growers also mentioned that they would still plant cover crops if financial support was not provided by DF&WT but they may plant fewer acres. One farmer stated he would not plant cover crops at all if the Greenfields Project (Winter Cover Crop Program) did not exist, because without financial support from DF&WT, the expense of cover cropping outweighs the benefits. Some growers would only plant cover crops early without the support of DF&WT and others would probably plant after DF&WT's usual deadlines.

Besides the cost of establishment, many growers stated that there was not much, if any, extra costs associated with cover cropping. Some farmers use glyphosate herbicide in the spring to deal with weeds and excessive growth of the cover crop itself and extra tillage is often required in the spring.

While some farmers felt that the financial aid given by DF&WT is not enough to cover the costs associated with cover cropping, others felt that the amount was sufficient. One farmer mentioned that if the payment was higher people may just abuse the system. Others felt that DF&WT should be supporting farmers because they are in effect often simply feeding waterfowl with the cover cropped fields.

Comparison with Past Attitudes

In 1998 a very similar set of questions was asked to local farmers, and general trends were summarized by G. G. Runka Land Sense Ltd. The perspective included the opinions of participant farmers, Professional Agrologists, and Runka's personal experience, unlike the 2009 farmer interview summary which focused exclusively on participant farmers. Most of the trends and opinions from 2009 are the same as they were in 1998.

Both then and now, farmers agreed that soil quality improved as a result of having cover crops, mainly due to increases in organic matter, although it is difficult to prove in the short term. Similar to today, some farmers preferred broadcast seeding and some preferred drilling. In 1998 preference was determined by expense and weed control, while today expense and soil moisture are the main determinants. Cover cropped fields retain moisture longer than bare fields in the spring, causing a delay in spring planting and field management.

Winter-killed cover crops were preferred then and now. In 1998 nitrogen relationships were considered to be improved in the winter-killed cover crops, meaning that a lower C:N ratio made the nitrogen more readily available to plants. This opinion is contrary to the findings of Odhiambo and Bomke (2000) who found that nitrogen availability was low following cereal cover crops. Today the main reasons that barley is preferred are that it produces biomass that is able to withstand grazing pressure, and causes less spring delay than winter-hardy cereals.

The limiting factors were weather and availability of time, and today those are still the predominant limiting factors. Today crop rotation is also an important factor, since the spring delay caused by cover crops is more of a set-back for some crops than others. Growers still cannot grow overwintering cauliflower, turnip, brussel sprouts, peas, beans, winter wheat, rye, and grass forage without being impacted by waterfowl feeding.

In 1998 farmers considered planting date an important determinant of soil conservation value of a cover crop, with later planted cover crops more beneficial to waterfowl than soil conservation; they still believe this today. In both surveys farmers also believed that cover crops planted in October provide little benefit to soil. Farmers continue to believe that flexible deadlines for planting date based upon weather are the best way to gauge planting date recommendations, although currently the deadlines are not weather dependent. However, the planting date deadline of October 9 is so late that it is not limiting.

Farmers in 1998 noticed that later planted crops were preferred by birds, especially fall rye; in 2009 farmers also noticed that later planted cover crops are preferred by waterfowl, especially wheat, as well as fall rye and barley. With respect to the soil benefit, early planting was emphasized and the majority of farmers in 1998 preferred winter wheat, although winter-killed cereals were favoured for improved nitrogen relationships. Currently farmers still believe that early planting is most beneficial to the soil, but they now believe that the best crops for soil conservation are barley and fall rye because they accumulate the most biomass. In 1998 farmers believed that the Winter Cover Crop Program provided an incentive to improve soil and that it reduced the risk of waterfowl consuming forage grass. Today views largely coincide with those of eleven years ago.

Section 4: Cover Crops and their Role in Wildlife Management

Key Points

- Winter cover crops are a food source for herbivorous waterfowl including Snow Goose, American Wigeon, Mallard, Northern Pintail, and Trumpeter Swan during fall migration, wintering period, and spring staging.
- Agricultural food sources may be an important way of maintaining waterfowl populations despite declines in marsh habitat over the past century.
- Waterfowl can cause damage to perennial forage crops (hay and pasture) and cover crops can mitigate this damage by acting as alternative feeding areas, luring waterfowl from the perennial forage.
- Agricultural food "subsidies" for waterfowl may increase their populations by decreasing winter mortality and improving breeding condition.
- Snow Geese can graze sports fields in Richmond and are an aviation safety hazard at the Vancouver International Airport; cover crops are an important component of any strategy to lure Snow Geese away from these areas.
- Shorebirds including Dunlin and Black-bellied Plover also use cover cropped areas to feed on invertebrates.
- Sandhill Cranes feed on newly sown cover crop fields during fall migration.
- Spring cereals seeded in August can provide roosting habitat for grassland raptors like the Northern Harrier and Short-eared Owl before the crop is killed by frost in mid-winter.

The Fraser River delta is the largest estuary on the Pacific coast of Canada. It also supports the highest density of wintering water birds in Canada and is an important stopover along the Pacific Flyway for many migratory birds (Butler and Campbell 1987). Herbivorous waterfowl including Trumpeter Swan (*Cygnus buccinator*), Lesser Snow Goose, American Wigeon, Mallard (*Anas platyrhynchos*), Northern Pintail (*Anas acuta*), and to a lesser extent, Green-Winged Teal (*Anas crecca*), Canada Goose, Greater White-Fronted Goose (*Anser albifrons*), and Cackling Goose (*Branta hutchinsii*), feed on agricultural crops during fall and spring migration and winter. Crops consumed include winter cover crops, grain, and perennial forage grasses and harvested vegetable residue (e.g., potatoes). Waterfowl can graze perennial forage fields, causing dramatic economic losses (Zbeetnoff and McTavish 2004). Waterfowl also limit farmers from planting over-wintering cauliflower and winter cereal (Temple and Bomke 2001). These issues can cause farmers to resent the presence of waterfowl.

Winter cover crops can play a role in reducing conflict between forage producers and wildlife; they can function as alternative feeding areas for waterfowl, luring them away from perennial forage fields. In addition to providing food for waterfowl in early winter and spring, winter cover cropped fields provide feeding habitat for shorebirds and Sandhill Cranes, and roosting habitat for some birds of prey.

The Delta Farmland & Wildlife Trust promotes the provisioning of food to waterfowl by encouraging farmers to plant cover crops. It is difficult to know whether there has been an increase or decrease in populations of waterfowl species which feed upon cover crops due to the lack of baseline data prior to land clearing for agricultural production. On the one hand, the

conversion of marsh and grassland areas to agriculture has increased the amount of energy-rich food available to waterfowl and thus some species' populations may have increased (Butler 1992). On the other hand the loss of natural habitat has been linked to decreases in waterfowl populations (Butler 1992); most likely the landscape level habitat changes have led to an increase in some species' populations and a decrease in others.

Waterfowl Feeding on Agricultural Land and General Population Trends

Dabbling ducks are opportunistic feeders, and both intertidal marshes and farmland are important feeding habitat (Lovvorn & Baldwin 1996). Dabbling ducks in the area, particularly American Wigeon, Mallard, and Northern Pintail feed on cover crops. They are all migratory species, and populations are much higher in the winter than the summer (Butler and Campbell 1987). In the intertidal flats of the Fraser River delta, dabbling ducks eat invertebrates and eelgrass; American Wigeon feed exclusively on vegetation, whereas Northern Pintails and Mallards feed on a combination of vegetation and invertebrates (Lovvorn & Baldwin 1996). Research has shown that intertidal food is not sufficient to support their populations through winter, and all three species feed on agricultural land when intertidal food is depleted (Lovvorn & Baldwin 1996). With dabbling ducks shifting to agricultural land, the impact of marsh habitat loss on these species may be reduced. In general, it is likely that waterfowl use of farmland habitat around the world has increased in the last century because natural habitats have decreased in size and the availability of highly palatable crops on farms has increased (Jefferies & Drent 2005).

There are three swan species present in the Fraser River delta: the Tundra Swan (*Cygnus columbianus*), the Trumpeter Swan, and the introduced Mute Swan (*Cygnus olor*). Of these, both Tundra Swans and Trumpeter Swans feed on farm fields as well as foreshore marshes (Butler and Campbell 1987). Tundra Swans are much less common than Trumpeter Swans, and when Tundra Swans are present they are often seen in mixed flocks with the Trumpeter Swans. The Trumpeter Swan was once under threat of extinction because of hunting, but now populations are growing and Trumpeter Swans in BC numbered over 23,000 in 2001 (Canadian Wildlife Service 2004). Local research has demonstrated that swans use potato fields and cover crops, and rarely use perennial forage fields (DF&WT, unpublished data).

The Wrangel Island Lesser Snow Geese are the only population of snow geese that breed in Asia, and have significant conservation value. Snow Geese used to breed on the Siberian mainland near Wrangel Island, but those populations have declined significantly and are currently at remnant levels (Syroechkovski 1997; Pacific Flyway Council 2006). Snow Geese from Wrangel Island overwinter in two large geographic locations: the Fraser River delta and the Skagit River delta in north Washington State, and the Central Valley of California (Pacific Flyway Council 2006). Snow Geese that winter on Delta belong to the Fraser/Skagit sub-population. The Fraser/Skagit subpopulation has increased over the last 15 years, and a greater proportion of Snow Geese now winter on the Fraser and Skagit deltas compared to California's Central Valley (Pacific Flyway Council 2006; William et al. 2008). On the Fraser River delta Snow Geese feed on sedges such as American three-square bulrush rhizomes, and agricultural crops including residual potatoes, perennial forage and winter cover crops (Boyd 1995).

Not all waterfowl species feed on agricultural land, but for those species which do, populations across North America and Europe have increased significantly since the 1950s

(Owen & Black 1991, Nichols et al. 1995). The population increases are due to several factors, but the provisioning of agricultural foods, the establishment of refuges, and presence of a warmer climate are suspected to be the main causes (Abrahams and Jefferies 1997; Abrahams et al. 2005a; Fox et al. 2005). Beginning in the late 1940s and early 1950s agricultural crops such as corn, rice, forage grasses, and cereals became abundant in the winter ranges of both North American and European wild geese. This, in combination with the creation of hunting-free refuges in and around agricultural areas, encouraged geese to feed on these crops (Abrahams and Jefferies 1997). The inclusion of these foods in their diet decreased mortality and improved the body condition of birds returning to their breeding grounds (Owen and Black 1991; van Eerden et al. 1996). This resulted in an increase in the number of offspring fledged because as body condition improves geese produce more offspring (Ankney and MacInnes 1978; Fox et al. 2005). Warmer climates over the past 50 years have allowed geese to expand their winter range further northward into agricultural areas (Abrahams and Jefferies 1997). Warming in the arctic has reduced breeding failures caused by harsh weather, allowing recruitment to remain high. Reduced hunting may have aided the growth of some European goose populations (Owen 1990; Ebbinge 1991; Owen and Black 1991) but hunting failed to control population growth in North America and harvest rates decreased despite steady and even increased hunting pressure (Abrahams and Jefferies 1997). In one dramatic case, population waterfowl increases have been linked to degradation of breeding grounds; the mid-continent population of Lesser Snow Goose increased 5-7 percent per year from 1960 to the mid 1990s, and the sensitive salt marsh summer breeding ground has been negatively impacted as a result (Abraham et al. 2005).

A trend of increasing waterfowl populations may be occurring in the Fraser River delta as well. However, Butler and Campbell (1987) conjecture that because of the reduction in marsh habitat to 21% of the size that it was a century ago, duck populations are lower today than they were at that time. According to Campbell et al. (2001), dyking in the late 1800s and the reduction in marsh habitat and sloughs after the drainage of Sumas Lake in 1924 significantly reduced populations of ducks and geese. Thus, there are factors which could be causing some waterfowl populations to increase (increase in food due to agriculture and the introduction of non-native eelgrass to intertidal flats) and factors that could be causing populations to decrease (habitat loss or alteration and hunting).

The Christmas Bird Count is an annual event conducted by citizens throughout North America on one day within a two week window (Audobon 2009). Based on the Ladner Christmas Bird Counts, it appears that American Wigeon and Northern Pintail populations have fluctuated year to year since 1957 but there is no general increasing or decreasing trend (Figure 4). For Mallard, however, populations seem to have increased since 1957. Both Christmas bird counts and aerial surveys indicate that Trumpeter Swan populations are increasing (Figure 5 and Figure 6, respectively).

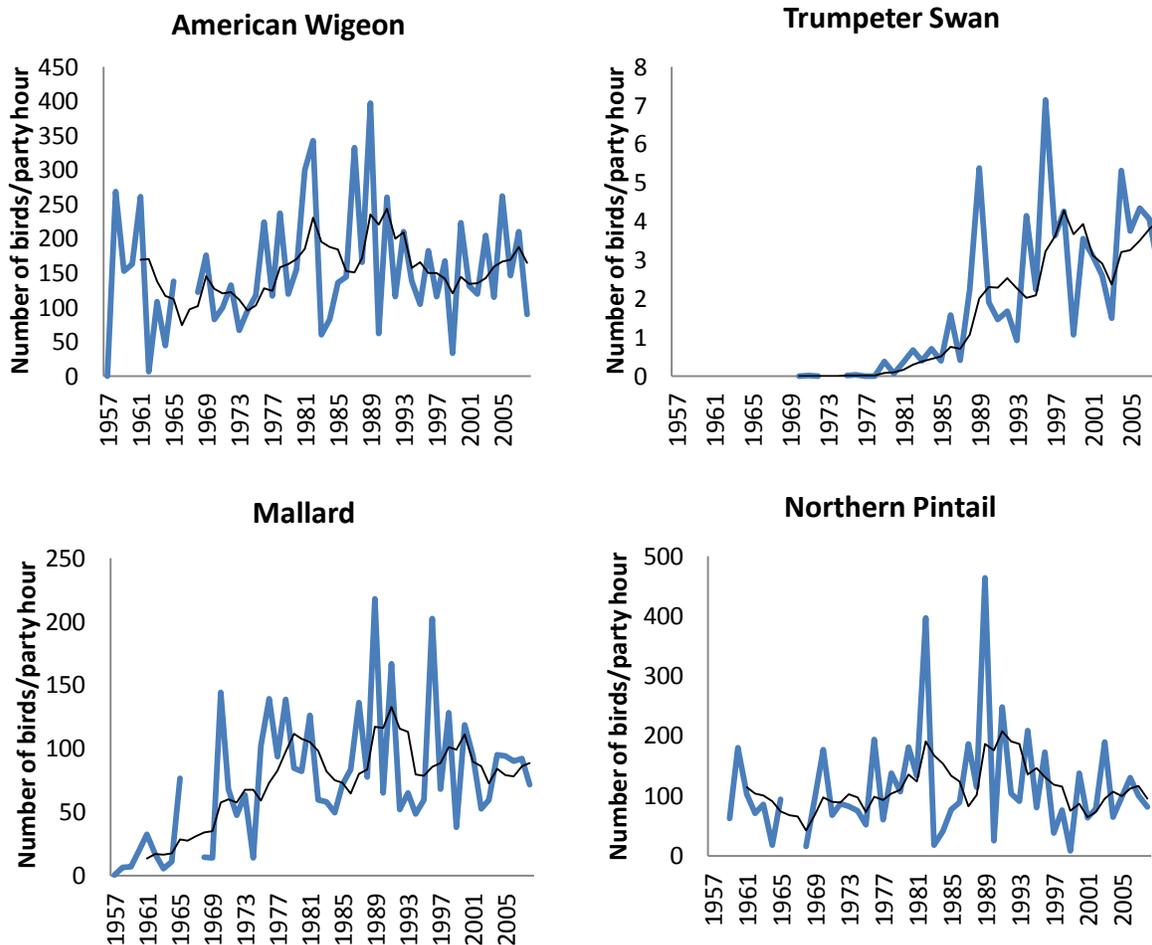


Figure 4. Number of birds per party hour for the annual Christmas bird count (blue line), which began in 1957 in Ladner. The five year averages are also indicated on the graphs (black line).

Since the first survey of populations on Wrangel Island in 1970, the Snow Goose population decreased from 150,000 to 50,000 in the mid 1970s, fluctuating until the 1990s. The population has been increasing steadily since then. In 2004 and 2005, the most recent data available, the population was estimated to be 120,000; thus it is almost as high as it was in 1970 (Pacific Flyway Council 2006). A study of mid-continental Lesser Snow Goose populations has shown that the intensification of agriculture has caused populations to increase since 1948 (Jefferies et al. 2004). The number of geese overwintering in California has decreased since 1970, and overwintering activity in British Columbia and Washington has increased (Hui et al. 1998, Pacific Flyway Council 2006). It is unclear whether Snow Geese are migrating to BC and Washington instead of California, or whether other dynamics are causing the shift in population numbers (Williams et al. 2008).

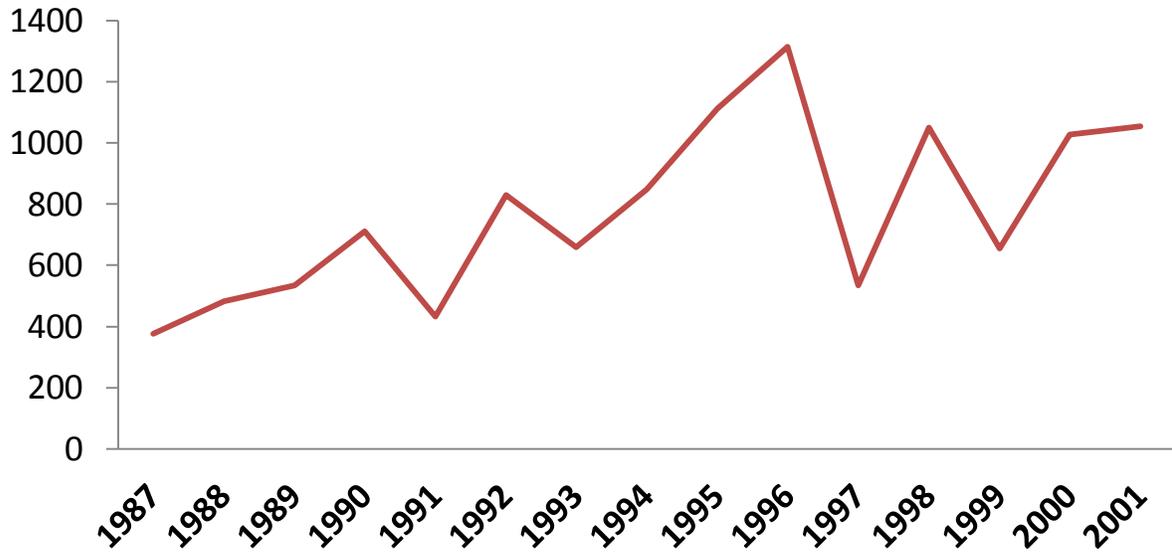


Figure 5. Swan population estimates based on aerial surveys. Data from S. Boyd, 2002, Environment Canada, Canadian Wildlife Service.

If the sub-population which overwinters in California continues to decrease and/or redistribute to BC and Washington, this region will become more important in supporting the Wrangel Island Snow Goose population. Since the first population estimates in 1948, (i.e., 26,000 individuals overwintering in the Fraser River and Skagit River) the Snow Geese overwintering in BC and Washington have increased from the 1980s onwards (Figure 5).

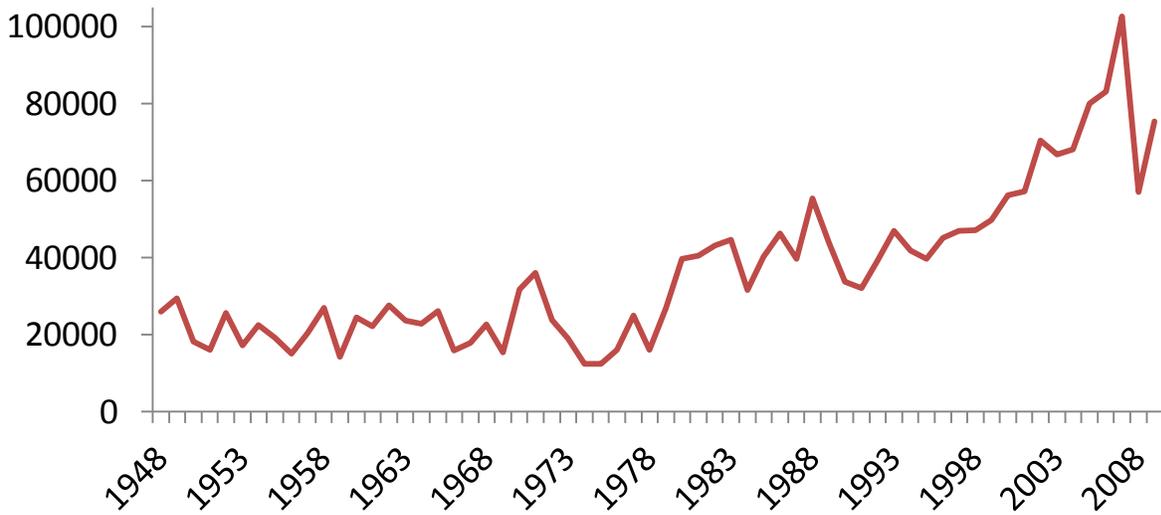


Figure 6. Population estimates for Snow Geese of the Fraser/Skagit subpopulation from 1948 to 2005.

The population hit a peak in 2007 with a record of 105,000 individuals, while the most recent count in 2009 was 75,000. This growing Snow Goose population is suspected to be causing

decline of three-square American bulrush (*Schoenoplectus americanus*) in marshes of the lower Fraser (S. Boyd pers. comm. 2010). Depletion of marsh vegetation could have negative effects on fish or other bird species. It is likely that the pressure on perennial forage fields has increased with the growing Snow Goose population.

Role of Winter Cover Crops in Waterfowl Management

Winter cover crops provide feeding habitat for several species of waterfowl. The lower Fraser River delta has changed greatly since the 1800s, and several populations of waterfowl are now dependent on agricultural habitat. Winter cover crops provide food for waterfowl, which is influenced by crop management and species selection (see "**Section 6: Managing Cereal Grasses as Waterfowl Lure Crops: Investigating Planting Dates and Waterfowl Feeding Ecology**").

In relation to the conflict between farmers growing forage crops and waterfowl, winter cover crops can be considered 'Alternative Feeding Areas' (AFA's). The goal of an AFA is to lure waterfowl to a crop they prefer instead of scaring waterfowl away from cash crops (McKay et al. 2000). They can be the most cost-effective way to deal with waterfowl feeding on agricultural crops. A British study found that AFA's were the most economical way to deal with waterfowl-farmland conflict between Brant Geese (*Branta bernicla*) and farmers with pasture and cereal crops (Vickery et al. 1994).

Snow Geese overwintering on the Fraser River delta prefer to feed on crops with the highest concentrations of crude protein and simple carbohydrates—cover crops, potatoes, and barley grain—before feeding on perennial forage (Bradbeer 2007). Once cover crop and potatoes are depleted Snow Geese feed on perennial forage, especially in the spring. Perennial forage contains lower concentrations of protein and sugar and higher fiber content, but as the more palatable grass is depleted, Snow Geese switch to perennial forage. New growth of both perennial forage fields and winter cereals is palatable for Snow Geese in the spring.

A portion of foreshore marsh habitat traditionally used by Snow Geese is located off the west of Sea Island, adjacent to the Vancouver International Airport, YVR. Birds are considered a risk for damage to aircraft, with the potential to cause harm to humans. Searing (2005) produced a risk assessment for wildlife at the Vancouver International Airport, and found that the heavier the bird the more risk it poses. According to his research, ducks, geese, and gulls pose the greatest risk to aircraft, and Snow Geese scored the highest in the risk assessment (Searing 2005).

Due to the exclusion of Snow Geese from marsh habitat on Sea Island, their ability to acquire sufficient food on marsh habitat is reduced. Providing Snow Geese with an alternative food source is important if their populations are to be sustained, and if scaring is to be effective. Winter cover crops can provide an alternative food source to Snow Geese and thus partially compensate for their exclusion from Sea Island. DF&WT is investigating different strategies to maximize the number of birds supported by cover crops, such as manipulating planting date and cover crop type ("**Section 6: Managing Cereal Grasses as Waterfowl Lure Crops: Investigating Planting Dates and Waterfowl Feeding Ecology**").

Waterfowl have adapted to a diet of agricultural crops, acquiring significant portions of their diet from farmland. If waterfowl continue to use the Fraser River delta, they are likely to continue feeding on farmland. Because much of their natural habitat has been altered, Snow

Geese are dependent on agricultural crops in order to continue to survive (Jefferies & Drent 2006). American Wigeon, Northern Pintail, Mallard, and Trumpeter Swan also depend on agricultural habitat, and their fate is inextricably linked to agricultural production and practices.

With the exception of Snow Geese, there is not enough data to determine whether populations are increasing on the Fraser River delta in a manner similar to waterfowl populations in other parts of North America. Since settlement in the late 1800s, the majority of waterfowl habitat has been converted to agricultural land, the YVR airport, and developed for housing, golf courses, transportation corridors, and other commercial and industrial ventures. One could argue that the humans inhabiting the area have a responsibility to compensate for that loss of habitat. There are uncertainties about what waterfowl require in order to maintain their populations, and climate change will likely influence the breeding grounds of waterfowl in Canada (Johnson et al. 2005). Given these uncertainties and that there are factors (such as temperature change in their breeding grounds) that are difficult or impossible to control even if understood, DF&WT is implementing the precautionary principle, and managing the landscape to maintain existing waterfowl populations.

Sandhill Cranes

Sandhill Cranes (*Grus canadensis*) stage on the lower Fraser River delta during fall migration. The cranes feed on several types of agricultural crops, including harvested bean, pea, and corn fields, harvested grain fields, cultivated fields, and winter cover crops (Hemmera 2009). Habitat use studies of Sandhill Cranes in Delta show that the birds use cover crop fields more than any other crop type. Cranes appear to feed on the freshly germinated seed of cereal cover crops that have been planted several days beforehand (Hemmera 2009). Planting cereal cover crops between early and late September to coincide with migration provides Sandhill Cranes with a food supply on their southward migration.

Grassland Raptors

Winter cover crops can provide roosting habitat for Northern Harrier (*Circus cyaneus*), which occur in high densities during winter (Butler 1992). They generally use open habitats including marsh, grass fields, sloughs, beaches, and mud flats in the Fraser River delta (Butler & Campbell 1987). They mostly feed on small mammals and avoid cultivated fields for hunting (Butler 1992). Although they are not very valuable as feeding habitat, Northern Harriers have been seen using cover cropped fields as communal roosting sites (Bradbeer and Halpin 2010, pers. obs.).

The Short-eared Owl (*Asio flammeus*), a species of Special Concern under COSEWIC, also can use winter cover crops as roosting habitat. Its populations have decreased on the Fraser River delta due to loss of grassland and marsh habitat (Butler & Campbell 1987). They are irruptive in their distribution because they will migrate to areas where food is abundant (Cooper & Beauchesne 2004). They can roost communally in the winter, on the ground in tall grass, shrubs, or hedge rows (Cooper & Beauchesne 2004). Like Northern Harriers, they have also been seen roosting on winter cover cropped fields (H. Middleton, October 2009, pers. comm.).

The ability for winter cover crops to provide roosting habitat to grassland raptors is not as significant as other roosting habitats such as old fields and shrubby areas. They are more

likely to be used if there is a standing crop, such as early planted spring cereals during late fall, before the crop has winter-killed. Nonetheless, it is interesting to note that winter cover cropped fields can provide a benefit to some grassland raptors.

Shorebirds

Twenty-nine species of shorebirds can be found in the Fraser River delta (Butler & Campbell 1987), including Western Sandpiper (*Calidris mauri*) and Dunlin (*Calidris alpina*) at internationally significant numbers (Butler 1992). Shorebirds feed on invertebrates, and many shorebird populations across North America are declining, including Western Sandpiper and Semipalmated Sandpiper (*Calidris pusilla*) on the Pacific Coast of Canada (Donaldson et al. 2000).

Farmland provides foraging habitat for some shorebirds; many, including Dunlin, Western Sandpipers, and Black-bellied Plovers (*Pluvialis squatarola*), forage on farmland between December and March (Butler 1992). Loss of intertidal foraging habitat may be offset by farmland which provides feeding habitat. A study of Dunlins on the Fraser River delta found that they acquire approximately 38% of their diet on agricultural land (Evans-Ogden et al. 2008b). Invertebrates in estuarine habitats burrow deeper when it rains, but on terrestrial habitat they move closer to the surface, thus shorebirds may be able to maximize their caloric intake by alternating between mud flats and farmland depending upon the weather. According to Butler (1992) Dunlin and Black-bellied Plover are often spotted on agricultural land, using it for feeding in an increasing trend from November to March, and they mostly prefer ploughed fields close to the foreshore (Butler 1992). Dunlin prefer foraging on intertidal habitats, but also forage terrestrially, and favour bare agricultural land or land with short vegetation (Shepard et al. 2003). Winter cover cropped fields also provide feeding habitat for several species of shorebirds, and waterfowl grazing increases the benefit of cover cropped fields to shorebirds (Shepherd et al. 2003). Shorebirds may be able to find invertebrates under the dead vegetation of winter-killed spring cereal cover crops. It is unclear whether winter-killed spring cereal mulch provides more invertebrate prey for shorebirds than bare fields.

Section 5: Analysis of Historic Cover Crop Grazing Surveys

Key Points:

- Spring cereals tend to be planted between mid-August and mid-September whereas winter cereals tend to be planted between mid-September and early October.
- The autocorrelation between planting date and cover crop type makes it difficult to evaluate cover crop management.
- It appears that cover crop planting date influences both the amount of soil cover throughout the winter as well as the extent of waterfowl grazing.
- Simple field estimates of percent cover and crop height are accurate predictors of crop biomass; when attempting to estimate cover crop biomass, these methods should be used instead of labour intensive clipping.
- Late planted winter wheat and fall rye are grazed extensively in early fall and winter while barley and oats are grazed more uniformly across the winter.

Analyzing Field Data from Past till Present

In 2009, the DF&WT conducted an analysis of the field data collected between 1990 and 2008. The ultimate goal of this analysis was to determine which winter cover crops and planting practices are the most effective, both in terms of maintaining soil fertility and providing food for waterfowl. More specifically, DF&WT's objectives were to determine how planting date and crop type affect soil cover, the amount of crop biomass available to waterfowl and the amount of organic matter available for incorporation into the soil. Grazing intensity and crop biomass variation throughout winter were also observed. These measures were collected to better understand the ecology of winter cover crops, which aid in the management of both soils and waterfowl in Delta.

Data collected from fields with waterfowl exclosures in 2004 was used to analyze the extent to which birds reduced the biomass of winter wheat. This data was used to determine if easily obtained metrics of cover crops, crop height, and percent of ground cover could be used as accurate estimates of biomass. The effect of planting date on crop cover and crop biomass was also reviewed. Grazing data was used to identify seasonal patterns in grazing intensity and to examine differences in grazing intensity between crop types. The quantity of food available for waterfowl upon their arrival in fall and how food availability changed across the winter season was assessed as well. Finally, soil protection provided by different crop types was compared by examining the average amount of cover provided by each crop type over the winter season.

Statistical Methods

Over 15 years of cover crop data is available, but there are several different layout formats and data collection methods. Appendix C outlines the various datasets that exist. Biomass data was collected in 2004 and a mixed model was used to track differences in biomass between grazed and ungrazed exclosures over time. All data used in parametric tests was Box-Cox transformed. However, only raw data is presented in figures. Normality was examined using the Shapiro-Wilks test, and a Tukey test was used to conduct multiple comparisons following significant results from the ANOVA. Other than with the Tukey results,

no adjustments were made to significance levels to account for the number of comparisons conducted.

A regression was used to examine the relationship between actual biomass and biomass index. The biomass index was generated by multiplying crop height by crop cover. The grazing index, used in several analyses, was generated from field observation of grazing damage. Data collection consisted of recording the proportion of each field that was lightly, moderately, and heavily grazed. The proportions were then multiplied by constants (grazing intensity = proportion of light grazed*0.25 + moderate grazed*0.5 + heavy grazed*1). A mixed model was used to test the effects of waterfowl grazing on winter wheat biomass compared to winter wheat in waterfowl exclosures. In this analysis, the effect of treatment (exclosure versus open) on biomass was tested, and field ID was considered a random variable to account for the repeated measurements taken on each field. Relationships between planting date and both March biomass and March crop cover were tested using a Pearson's correlation

To assess seasonal variation in grazing intensity, as well as crop biomass, four separate two-way ANOVAs, one for each crop type, were used. Sampling month and year were independent variables and grazing intensity was the dependent variable. This enabled a comparison of grazing intensity at the four different time points. Four separate two-way ANOVAs, one at each sampling period, were also used to compare the amount of grazing each crop type received. Crop type and year were independent variables and grazing intensity was the dependent variable.

A two-way ANOVA was used to compare the amount of biomass provided by each crop type in November, and another was used to compare how much ground cover each crop type provided during the winter season. Crop type and year were the independent variables in both tests, while crop biomass was the dependent variable for crop type biomass comparisons, and seasonal crop cover was the dependent variable when analyzing ground cover.

Data Discoveries and Discussions

Crop Biomass Index

Biomass is the amount of plant material per unit area. Greater crop biomass usually results in more soil cover, which helps protect the soil from erosion and provides organic matter to improve soil fertility (see "**Section 2: The Role of Winter Cover Crop in Fraser River Delta Crop Rotations**"). In addition, wildlife managers are interested in biomass because it is a measure of how much food is available for waterfowl.

Standard measurements of crop biomass are obtained by clipping the crop in a known area and then drying and weighing the clippings to obtain dry biomass. This process is a labour intensive and therefore expensive way to determine crop biomass. For this reason, it is beneficial to use quick and easily obtained field measures that would be good approximations of biomass. DF&WT visually assessed the height and percent cover of winter cover crops during several years of the Winter Cover Crop Program, with a desire to test if these more easily obtained measures are good approximations of actual biomass. In 2004, data on crop height, crop cover, and actual dry biomass were collected from 20 different winter wheat fields at four time periods between December 2004 and March 2005. Crop height was multiplied by percent ground cover (biomass index) and compared with actual dry biomass to determine if they were

positively correlated, as would be expected if the index provided a reasonable estimate of biomass.

A significant positive correlation was found between the biomass index and actual biomass, with the index accounting for 72% of the variation in dry biomass ($t_{319} = 28.53$, $p < 0.001$, $R^2 = 0.72$). Although dry biomass data was only available for winter wheat, it is reasonable to assume that this index would be similarly related to biomass in other crops. This assumption is supported in part by Duynstee's (1992) pilot study of the Greenfields Project. Duynstee reported a positive correlation ($r = 0.75$) between crop height and actual dry biomass using data pooled for a winter wheat and barley. Based on these two results, the biomass index was considered a reasonable estimate of biomass and was used in later analyses for all crop types.

Experimental Evaluation of Grazing effects on Winter Wheat

It is well established that foraging by waterfowl can reduce the biomass of cereal crops (Flegler et al. 1987, Summers 1990, Temple et al. 2001). In 2004, exclosures were used to examine the effect of waterfowl grazing on cereal cover crop biomass between February and March. Using a mixed model, dry biomass of winter wheat in exclosures were compared with plots of wheat not protected from waterfowl. The resulting analysis showed a significant interaction between plot type and month ($F_{1, 210} = 6.21$, $p = 0.014$), that is: during February and March biomass increased in exclosures, while open plots had similar amounts of wheat in both months (Figure 7). Exclusion plots had 25 % more biomass than did plots open to waterfowl grazing.

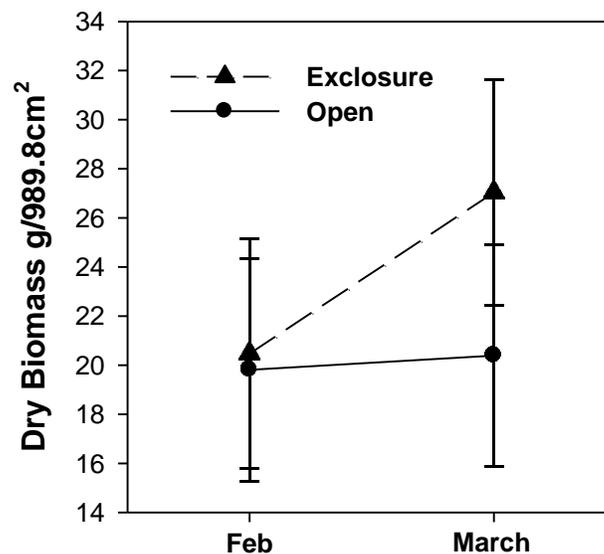


Figure 7. Predicted means \pm SE from a mixed model comparing biomass inside and outside of waterfowl exclosures. Data was collected on winter wheat in 2004 and was originally collected as g/989.8cm².

Planting Date

The date which a cover crop is planted determines how long it can grow before grazing waterfowl arrive in the fall. Therefore, planting date is probably one of the most important factors influencing crop biomass and crop cover. Furthermore, planting date of cover crops can be influenced through adjustments to the Winter Cover Crop Program guidelines. Currently, spring cereals must be planted before September 15 to be eligible for the Winter Cover Crop Program; winter cereals can be planted before the first week of October.

In order to determine how planting date affects crop cover and crop biomass, planting date and March ground cover and biomass were tested for correlations. Measurements from March were used for several reasons. First, biomass in March is a measure of organic matter available for incorporation into the soil just prior to spring tillage. Second, this was a way to investigate the effect of date on biomass and cover after a full season of waterfowl grazing. Correlations were conducted using data for barley and winter wheat because there was insufficient data for oats and rye. It was expected that less biomass and less crop cover in March would be found on fields when barley and winter wheat were planted later.

For barley, a negative relationship was found between planting date and crop cover and biomass index measured in March (cover: $R = -0.38$, $t_{106} = -4.21$, $p < 0.001$; biomass: $R = -0.27$, $t_{105} = -2.89$, $p < 0.001$). That is, when barley was planted later in the season there was a lower percentage of the field with crop cover and less biomass available to be incorporated into the soil. For winter wheat, a negative relationship was found between planting date and crop cover and biomass index, when these variables were measured in March (cover: $R = -0.55$, $t_{57} = -4.91$, $p < 0.001$; biomass: $R = -0.52$, $t_{57} = -2.89$, $p < 0.001$). That is, when winter wheat was planted later in the season there was a lower percentage of the field with crop cover and less biomass available to be tilled into the soil.

Differences between the four major crop types and the average annual planting date were analyzed as well. From these analyses, it was established that on average barley and oats (spring cereals) were planted 19 days earlier than winter wheat and fall rye (winter cereals). There are several reasons for observed differences in planting date between spring and winter cereals. Firstly, spring cereals planted after September 15 are not eligible for the Winter Cover Crop Program. Secondly, spring cereal seed is generally less expensive than winter cereal seed (see "**Section 3 Farmer's Perspectives: Operational Challenges and Opportunities of Cover Crops in Delta**"), reducing the cost of establishing a cover crop. Thirdly, residue from spring cereal cover crops can be easier to manage the following spring because the plants are frost-killed. Winter cereals that survive freezing temperatures can present challenges to farmers in Delta, including slowed soil drying in the spring, lower soil temperatures and abundant green manure that can be hard to incorporate into the soil without first mowing the cover crop (Odhiambo and Bomke 2007).

The consistent differences in planting date are critically important to consider given that a negative relationship between planting date and biomass and crop cover exists. Crop types differ in planting date and any differences between crop types in biomass or crop cover may simply be due to planting date rather than an intrinsic quality of the crop. However, these date effects were not included in subsequent analyses. Therefore, all further results reported should be considered in the context that date effects exist and are likely contributing to differences between crop types.

Grazing Intensity

DF&WT has been interested in quantifying grazing intensity in order to help understand waterfowl feeding patterns and resulting crop damage. To accomplish this, DF&WT has used visual assessments of grazing to create a grazing intensity index. In the field, the visual assessment requires the observer to categorize grazing as either light (less than 25% of an individual plant grazed), moderate (between 26 and 75% of a plant grazed), or heavily grazed (more than 75% of a plant grazed). Then the observer estimates the proportion of the field which falls into these three categories to the nearest five percent, or to the nearest percent for low values (below five percent). These numbers are then entered into the grazing intensity formula to generate a numeric value from 0-100 that describes the extent of grazing. For this study, the following formula was used:

$$\text{Grazing intensity} = (\text{proportion of field light grazed} * 0.25 + \text{moderate grazed} * 0.5 + \text{heavy grazed} * 1) * 100$$

Several species of waterfowl use agricultural fields as feeding habitat, including the Wrangel Island lesser Snow Goose population, Trumpeter Swans, a diversity of dabbling ducks including the American Wigeon, Northern Pintail, Mallard, and Green-winged Teal, and other goose species, including Canada Goose, Greater White-Fronted Goose, and Cackling Goose. Waterfowl grazing occurs on harvested vegetable fields, perennial forage grasses, unharvested grain crops, and agricultural weeds, as well as winter cover crops. Cover crops planted in the late summer and early fall can act as lure crops, potentially drawing waterfowl away from valuable perennial forage fields by providing them with an alternative source of food.

In the 2009 analysis, DF&WT wanted to summarize the available data on waterfowl grazing patterns of cover crops, particularly focusing on seasonal patterns in grazing intensity and differences in grazing intensity between crop types. Seasonal variation helps to better understand the timing of grazing. For example, do waterfowl graze heavily on cover crops in November and December, depleting available cover crops, and then move to other food sources for February and March? If grazing intensity differs between crops types, this may indicate a preference by waterfowl for a particular crop variety.

In 2006 and 2007, grazing intensity varied across the winter (barley (BAR): $F_{3, 306} = 291.56$, $P < 0.001$; winter wheat (WWT): $F_{3, 177} = 2.86$, $P < 0.001$; oat (OAT): $F_{3, 75} = 37.34$, $P < 0.001$; fall rye (RYE): $F_{3, 27} = 16.97$, $P < 0.001$). Generally, grazing continued on all crops as the season progressed with all crops ending up heavily grazed (Figure 7). Grazing intensity ranged between 60 and 80 percent by March for oats and winter wheat respectively, with grazing on barley and rye falling between these values. Despite similar patterns, there does appear to be some interesting differences between the varieties. For example, heavy grazing occurs early (November to December) on winter wheat and rye and then slows later in the season. Barley and oats, in comparison, appear to be grazed roughly at a similar rate (i.e., appears to follow a linear pattern) across the season. This data may suggest that waterfowl have largely depleted winter wheat and rye as food sources early, with grazing abating in January and March due to a lack of available biomass.

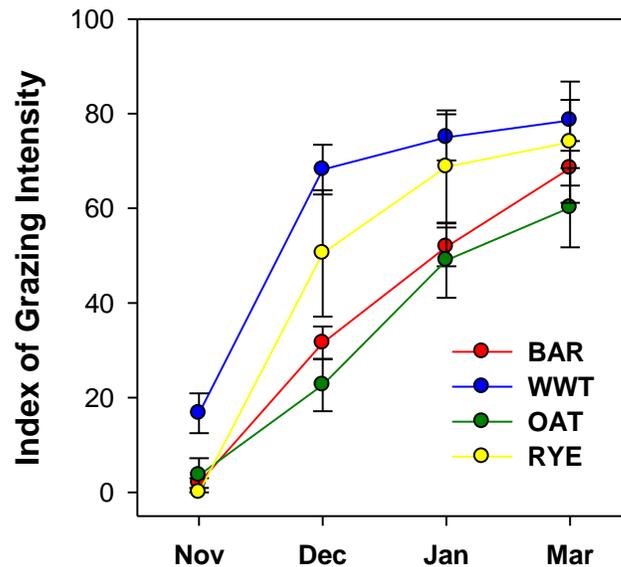


Figure 8. Changes in waterfowl grazing intensity across the winter season for years 2006 and 2007 in Delta. Means and SE are presented for non-transformed data.

To identify potential grazing preferences, the different crops types were compared for the degree of grazing incurred at the four time periods across the season (Figure 8). In 2006 and 2007, waterfowl grazing intensity varied between the four crop types at all four time periods, but only marginally in March (November: $F_{3, 207} = 5.23$, $P = 0.002$; December: $F_{3, 209} = 12.69$, $P < 0.001$; January: $F_{3, 211} = 5.43$, $P = 0.0013$; March: $F_{3, 208} = 3.14$, $P = 0.03$). Winter wheat incurred greater grazing than other crops at several time periods across the season. In November, winter wheat experienced more grazing than all other crops, but was equivalent to rye in December, and was more than barley, but equivalent to oats or rye in January. Although there was significant variability between crops in March, all crops incurred similar levels of grazing, and the Tukey results indicated that no one crop incurred significantly greater grazing damage than any other crop.

The results from the 2006 to 2007 monitoring suggest that waterfowl preferentially feed on winter wheat (i.e., early in the season there is more damage to winter wheat), shifting to rye and then oats and barley later on in the season. In 2006 and 2007, by March waterfowl appeared to graze the crops equally. In a previous Greenfields study, Temple et al. (1996) concluded that grazing intensity was higher for winter wheat than other crops, similar to the findings of the current investigations. Smith et al. (1996) suggested that these differences in grazing by crop type are independent of planting date (i.e. more grazing would occur on winter wheat planted at the same time as barley). However, without experimental evidence, the interpretation by Smith et al. (1996) is somewhat unreliable. Waterfowl may preferentially feed on younger plants (Temple et al. 2001), so they may favour late planted crops of any type. Based on these analyses, experimental manipulation of planting date to further investigate waterfowl preference for crop types is recommended.

An Overall Comparison of Grazing Intensity Data

DF&WT has collected grazing data for a number of years. However, data collection schemes varied across those years (see Appendix 3 for summary). Therefore, data was grouped by similar collection schemes, and was analyzed separately using the same statistical tests as those conducted for the most recent data collected in 2006 and 2007 presented above. This way, grazing data could be qualitatively compared in 1992-1997, 1999-2001, and 2006-2007, as the results indicate below.

Both similarities and discrepancies were found between the three data sets. For all three sets of data, winter wheat and rye fields were grazed more in both 1999-2001 and 2006-2007, or had a larger percentage that was grazed (fall 1992-1997) compared with barley and oats (Figure 9). Discrepancies between data sets exist when examining the grazing intensity measured in March (March measured grazing is the cumulative grazing across the year, or total grazing). The results from 2006 to 2007 suggested that by March there was no significant difference between crop types in the grazing intensity incurred, whereas the data from 1999-2001 suggested that winter wheat and rye had greater total grazing compared to barley and oats by March.

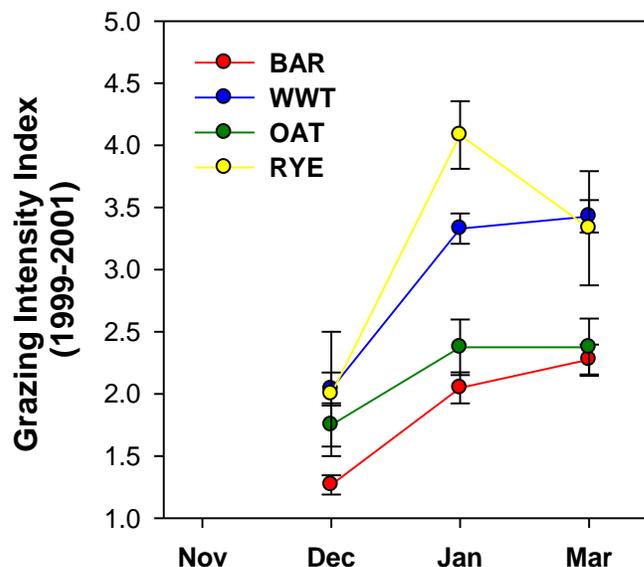


Figure 9. Changes in grazing intensity across the winter season for years 1999-2001. Means and SE are presented for non-transformed data. Grazing intensity in these years was measured on a 0-4 scale. The index was calculated in a slightly different manner than the index for 2006-2007.

Seasonal Changes in Biomass

Quantity of food available for waterfowl was determined using the crop biomass index as an indicator for food availability. Seasonal variation in biomass (i.e., changes in food availability throughout the year) was compared between cover crops, including the available biomass at the time waterfowl arrive in the fall. Crop cover (% of ground cover) is important to soil protection because it slows rain drops and surface water movement, thereby preventing

soil erosion and maintaining soil surface structure; soil protection provided by different crop types was compared by examining the average amount of cover provided by each crop type over the winter season. Also, cover crop biomass present in March functions as green manure for spring ploughing, and this analysis, crop biomass in March was compared in different crop types.

In 2006 and 2007, cover crop biomass significantly varied across the winter for all four crops (BAR: $F_{3,300} = 993.00$, $P < 0.001$; WWT: $F_{3,177} = 149.40$, $P < 0.001$; OAT: $F_{3,75} = 140.46$, $P < 0.001$; RYE: $F_{3,24} = 57.44$, $P < 0.001$). Generally, biomass decreased from November to March for all crop types (Figure 10), indicating that food availability provided by cover crops declines as the winter season continues.

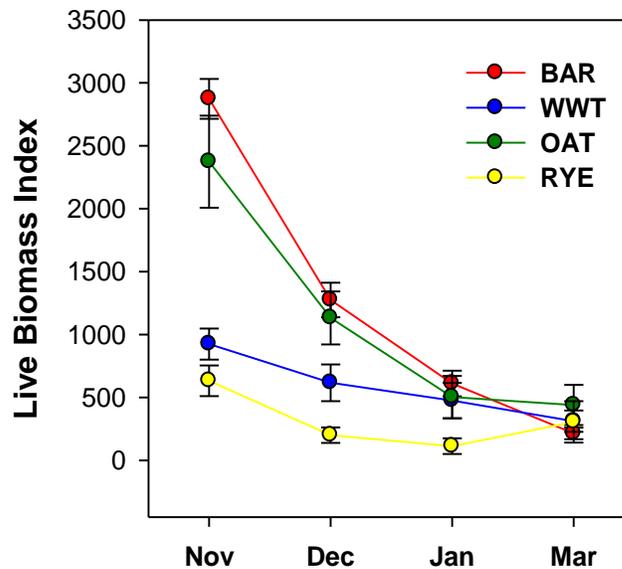


Figure 10. Changes in live biomass of cover crops across the winter season for years 2006 and 2007 in Delta. Means and SE are presented for non-transformed data. Live biomass was calculated from the biomass index (crop height * crop cover) controlling for the percentage of dead foliage.

As displayed in Figure 10, crop biomass was the highest in November and then declined across the season as a result of waterfowl grazing. For this reason, biomass measured in November was considered a measure of total biomass available for waterfowl consumption (i.e., biomass prior to grazing). Live biomass available for birds to eat in November varied by crop type ($F_{3,205} = 31.71$, $P < 0.001$), with barley and oats providing significantly more biomass for waterfowl consumption compared to winter wheat and rye (Figure 11). Fields planted with barley and oats had roughly 1.5 times more crop biomass per unit area than did fields planted with winter wheat or rye. Excluding the consideration that crops differ in nutrient content, these results suggest that barley and oat cover crops would provide more food to waterfowl. Again, barley and oats were planted 18-20 days earlier on average, which likely explains much

of the difference in crop biomass in November. Furthermore, older and taller crops tend to have lower concentrations of protein (Bos et al. 2005) and are therefore less nutritious for waterfowl, suggesting that a tradeoff likely exists between biomass (i.e., related to age and crop height) and nutrient content. Work by Temple et al. in 2001 suggests that later planted cover crops are more nutritious than earlier planted ones, sometimes regardless of crop type. While they did not conduct a formal statistical comparison between planting dates, crude protein concentrations appear to be higher in younger plants.

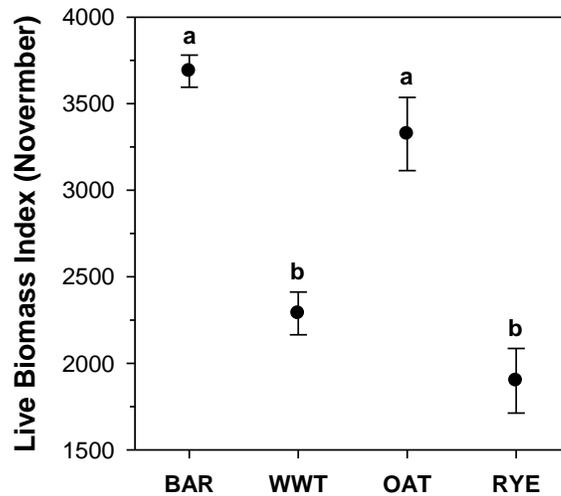


Figure 11. Mean \pm SE of the live biomass index in November from 2006 and 2007 in Delta. Letters indicate result of Tukey test: means with different letters are significantly different. Biomass scores have been corrected for the amount of grazing that had occurred by the time of sampling. This was necessary because some crops incurred greater grazing early on.

Seasonal average of percent crop cover, measured during November, December, January and March, was compared with March measurements of biomass index (organic matter available to work into the field). The average crop cover provided throughout the winter varied between the four main crops planted ($F_{3, 212} = 14.40$, $P < 0.001$), with barley and oats providing significantly greater cover than winter wheat and rye (mean \pm Se = barley $45 \pm 2\%$, oats 43 ± 4 , winter wheat $26 \pm 3\%$, rye 23 ± 3 ; Figure 12). Temporarily ignoring differences in planting date, this result would suggest that barley and oats may be better to plant if a crop's main purpose is to reduce erosion. Though the greater ground cover provided by barley and oats is, in part, the result of earlier planting, it may also be partially explained by waterfowl grazing preference for winter wheat and rye early in the season. The four crops also varied in the amount of biomass (in this case biomass = dead and alive plant material) present in March (biomass index: $F_{3, 207} = 3.3$, $P = 0.021$). Oats provided more biomass in March (greater biomass to plow into the field) compared to rye and winter wheat, but not significantly more than barley (Figure 13).

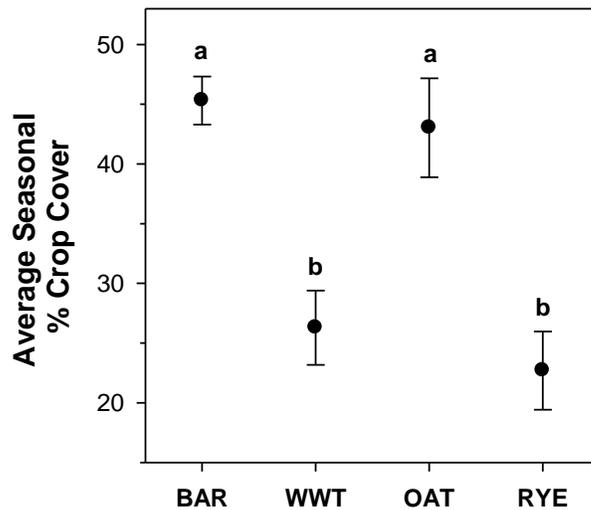


Figure 12. Average (of four sampling periods) % crop cover (means \pm SE) pooled for 2006 and 2007 in Delta. Letters indicate result of Tukey test: means with different letters are significantly different.

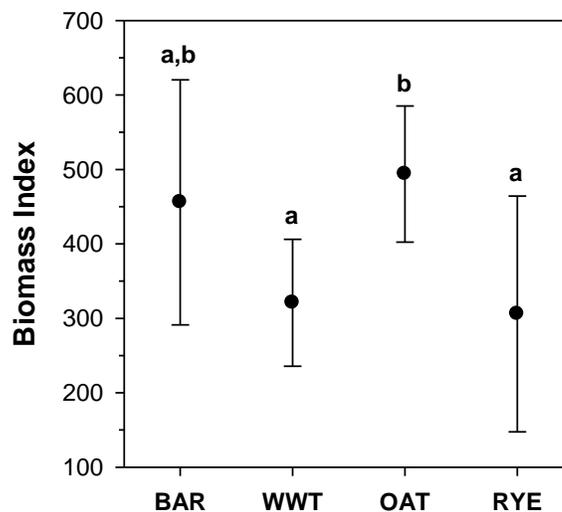


Figure 13. Mean \pm SE of biomass index for the major crop types in March for 2006 to 2007 in Delta. Letters indicate result of Tukey test: means with different letters are significantly different.

Conclusive Data: Biomass, Cover, and Grazing

The broad goal was to identify the most effective planting practices and crop types for maintaining soil quality and providing feed for waterfowl. Based on the results, planting date is an extremely important factor with regards to soil management and providing food to

waterfowl, with earlier planted crops better achieving these goals. However, no definitive statements could be made on the best crop type. Crop types are generally planted at different times in the fall making it difficult to separate the effect of planting date from the characteristics of each crop type.

Also, the simplified field measures collected by DF&WT used to generate a biomass index do approximate actual biomass. It is reasonable to use this field index of biomass to conduct further analysis on data collected between the years of 1990-2008. Based on the enclosure experiment, it appears that waterfowl grazing reduced winter wheat biomass by 25% between December and January, providing further evidence for the negative effects of waterfowl on crop biomass.

In general, grazing continued as the season progressed from November to March, with an average of 60-80% of the field showing evidence of grazing by March. Heavy grazing appears to occur on winter wheat and rye early in the season, with barley and oats grazed at a more uniform rate across the season. Upon the arrival of birds in fall, barley and oats have the most live biomass, about 1.5 times more, when compared to winter wheat and rye. As expected, the variation in biomass across the season was the mirror opposite of grazing intensity, that is, crop biomass decreased from November to March for all crop types. Finally, barley and oats provide more ground cover on average compared to winter wheat and rye. On average, barley and oats provided approximately 45% field cover across the winter season compared with approximately 25% by winter wheat and rye. Again, these results may simply be due to early planting of barley and oats, rather than an intrinsic quality of these crop types to provide better ground cover, biomass, and feeding habitat.

Section 6: Managing Cereal Cover Crops as Waterfowl Lure Crops

Key Points

- Planting date of winter cereals influences the number of waterfowl supported by a cereal cover crop; cover crops planted in late August and early September support more waterfowl than those planted in late September and early October.
- Winter cereals support more waterfowl than spring cereals because they do not frost-kill.
- Winter cover crops can offset waterfowl damage to perennial forage by providing an alternative feeding area but do not completely abate the damage.
- In 2010 the Winter Cover Crop Program was restructured to provide a larger cost-share to farmers who plant winter cereals in late August and early September.
- Novel cover crops, such as clover and forage grasses underseeded into grain, provide a broader range of options for managing soil and luring waterfowl from hay and pasture crops.

Introduction

This study examined patterns of habitat use by over-wintering waterfowl on the Lower Fraser River Delta (LFRD), with the goal of determining the efficacy of winter cover crops (specifically cereal grasses) as alternative feeding areas (AFAs) for waterfowl. Winter cover crops are important for agricultural soil management (Hermawan & Bomke 1997; Odhiambo and Bomke 2000), but also act as feeding areas for wintering and migratory waterfowl. Grazing waterfowl present many challenges to farming, aviation safety and recreation and attracting waterfowl to winter cover crops can play a role in reducing these conflicts.

Agriculture on the lower Fraser River delta is important for conserving internationally significant waterfowl populations. A range of waterfowl species use agricultural fields as foraging habitat, including the Wrangel Island Lesser Snow Goose population (the only population of Snow Geese to winter in Canada and breed in Russia), Trumpeter Swans (a previously endangered species), a diversity of dabbling ducks including the American Wigeon, Northern Pintail, Mallard, and Green-Winged Teal, and other wild goose species, including Canada Goose, Greater White-fronted Goose, and Cackling Goose (Butler and Campbell 1987). Agricultural fields contribute to the conservation of these species by providing waterfowl with food, in the form of harvested vegetable residue (e.g., potatoes), perennial forage grasses, cereal cover crops, unharvested grain crops, agricultural weeds, and invertebrates.

Conflict between waterfowl and agriculture can arise when the birds depress the yields of economically important crops, especially perennial forage grasses (hay and pasture grasses). Herbivorous waterfowl especially, Lesser Snow Geese and American Wigeon, can overgraze perennial forage grass, reducing spring yields or requiring that fields are reseeded. Data collected as part of the Delta Waterfowl Damage Mitigation and Compensation Program show that an average of 2,600 acres of forage is grazed annually (Delta Waterfowl Damage Mitigation and Compensation Program unpublished data 2009).

Waterfowl can come into conflict with other human activities as well. On the lower Fraser River delta, waterfowl pose a safety risk to the aviation industry at Vancouver International Airport (YVR), especially when large flocks of Snow Geese congregate on the foreshore marsh of Sea Island, Vancouver, directly in the flight path of approaching and departing aircraft. Snow Geese also graze recreational areas such as school playing fields in Richmond, BC.

Scaring birds away from important crops or air traffic corridors using human or mechanical scaring regimes can have some effect on the movement of birds, but it is important that alternative feeding areas are also available nearby so that waterfowl can graze undisturbed (Vickery and Summers 1992). It may be the case, as suggested by Vickery and Summers (1992), that the efficacy of bird scaring is lower when food resources become limited in supply. This may occur during periods of adverse weather conditions or when there is a lack of alternative feeding areas. Planting cereal cover crops as alternative feed in areas commonly used by waterfowl (e.g., farmland in Delta) could increase the efficacy of scaring regimes in other areas.

Cereal grasses planted as cover crops in the late summer and early fall can act as lure crops, potentially drawing waterfowl away from perennial forage fields by providing them with an alternative source of food. DF&WT's Winter Cover Crop Stewardship Program (formerly the Greenfields Project) provides a cost share to Delta farmers to plant spring cereals (barley, oats, spring wheat) and winter cereals (fall rye, winter wheat) as cover crops. Through this program, Delta farmers are paid a cost-share (per acre) to plant cereal grasses which are meant to benefit both soil fertility (by reducing winter erosion and increasing soil organic matter) and waterfowl conservation. Cereal grasses are used extensively by waterfowl and several studies show that both Snow Geese and American Wigeon will graze cereal cover crops before grazing perennial forage grasses (Bradbeer 2007; DF&WT unpublished annual report 2008).

Despite the presence of cereal cover crops on the landscape of Delta, waterfowl damage to perennial forage crops has not completely abated. Research conducted on Snow Geese shows that as potato residue, cereal cover crops and other alternative foods are depleted, the birds will begin feeding on perennial forage fields (Bradbeer 2007). Depletion of these alternative food sources usually occurs during mid winter, and it is between early March and mid April when the shortage of food appears to be most acute; Snow Geese make their most intensive use of perennial forage crops during these two months.

Managing cereal cover crops to provide greater amounts of biomass during critical periods may alleviate grazing pressure on perennial forage fields. This study will provide data that will help re-develop Winter Cover Crop Stewardship Program guidelines for planting winter wheat as a lure crop for waterfowl in spring. Snow Geese and dabbling ducks will be the focus species of the study because of their abundance in the area and their reputation for causing damage to perennial forage.

Recent evaluation of the Winter Cover Crop Stewardship Program reveals that many farmers plant barley and oats as cover crops in mid August to early September, and plant hardier winter cereals like fall rye and winter wheat from mid-September to early October. Barley and oats are preferred by farmers as early planted cover crops because they cost less than winter wheat, will frost-kill and provide organic matter for incorporation into soils during late spring. However, barley and oats desiccate on the soil surface after being killed by frost and provide little food for waterfowl in early spring. Winter cereals planted after mid-

September tend to accumulate less vegetative biomass compared to earlier (August) planted crops. Because they provide less biomass, cereals planted after mid-September are completely grazed in the fall and early winter.

Winter wheat will not frost kill like barley and oats, thereby remaining a viable food source into the spring. A winter wheat lure crop that survives into spring would provide significant spring feed for waterfowl; winter wheat planted in mid August has been shown to accumulate more biomass over winter than the same crop planted in mid-September (Temple *et al.* 2001). Based on these observations, planting winter wheat instead of barley and oats in mid-August should provide waterfowl with an alternative food source to perennial forage during spring.

Study Objectives

The goal of this project was to measure waterfowl use of various cover crops in order to provide a scientific basis for updating cereal management practices on the lower Fraser River delta. With these data, it will be possible to implement practices that maximize feed for wintering waterfowl while minimizing perennial forage crop losses. We examined waterfowl field use on a variety of winter cover crops, including winter wheat, oats, and barley, as well as perennial forage grass.

With accurate waterfowl use data it is possible to quantify the carrying capacity of different cover crops. Waterfowl defecate at a fairly constant rate while feeding so accurate estimates of the number of birds supported by crops can be attained using fecal pellet counts. By using this method for evaluating waterfowl use of winter wheat and perennial forage, it is possible to calculate the acreage of cereal cover crops required to support wintering waterfowl and offset their use of perennial forage crops.

The specific objectives of this study were to:

1. Determine how the planting date of winter wheat affects the number of migratory waterfowl that a farm field can attract throughout the wintering period (fall to spring).
2. Determine how effective planting date influences the ability of winter wheat at luring waterfowl from perennial forage crops.
3. Determine how planting date influences vegetation height and ground cover provided by cereal cover crops and quantify patterns of crop depletion throughout the winter.
4. Use the data collected to calculate the waterfowl carrying capacity of cereal cover crops as well as the acreage of cereal grasses required to offset damage to perennial forage crops.

Methods

Study Site

The Fraser River Delta is the largest estuary on Canada's Pacific coast (Butler and Campbell 1987) and located such that human and non-human interests overlap. Before European settlement the landscape of the lower floodplain was predominantly herbaceous vegetation including marsh and grassland (North *et al.* 1979). Since dyking and drainage in the late 1800's, there has been an increasing human presence and influence on the region. The land has value for humans and for wildlife, in different and sometimes conflicting ways.

Agriculture currently represents approximately 41% of the land use on the lower Fraser River delta, and the majority of the area is zoned as part of the Agricultural Land Reserve (ALR) and is thus meant to remain as agricultural land (Agricultural Land Commission 2009, Fraser 2004). The region produces a variety of crops, including potatoes, beans, peas, corn, cole crops (cabbage and rutabaga), other annual field vegetables, berries, perennial forage, and grain feed for livestock (Fraser 2004). The region produces a large portion of British Columbia's total potato production, 152,343 tonnes in 2001 (British Columbia Ministry of Agriculture Fisheries and Food 2003). Currently, the growing urban population in the Metro Vancouver area is competing with agriculture for the development of land for residential, commercial, and industrial land use, as well as the associated transportation corridors.

Many of our study plots were located on Westham Island, which is situated in the Lower Fraser River Delta (LFRD) at the mouth of the Fraser River. Westham Island is an important agricultural community comprised of arable land with some small scale livestock production. The George C. Reifel Migratory Bird Sanctuary and the Alaksen National Wildlife Area are both located at the northern end of Westham Island.

Data Collection

DF&WT study fields were comprised of 3 winter wheat fields planted in late August ("Winter Wheat Late Aug" treatment), 4 winter wheat fields planted in mid-September ("Winter Wheat Mid Sept" treatment), and 3 winter wheat fields planted in late-September to early October ("Winter Wheat Late Sept" treatment). Replicates with 5 fields of perennial forage ("Perennial Forage" treatment) as well as 12 fields of oats and barley ("Spring Cereal" treatment) were also sampled.

Beginning in October 2009, waterfowl habitat use was monitored by counting the fecal pellets that accumulated in permanent plots each week. This method was ideal for monitoring waterfowl use because it is cost effective and comparably accurate to other methods (Owen 1975; Bédard and Gauthier 1986). Counting individual waterfowl requires that study fields be monitored continuously to ensure no use is missed, and visual estimates of bird numbers can be inaccurate (Boyd 2000). Using visual estimates to quantify waterfowl field use is further confounded because some species (American Wigeon and to a lesser extent, Snow Geese) will graze fields at night when counts are difficult. Generally, waterfowl defecate between every 3-4 minutes (Bédard and Gauthier 1986, Mayhew 1988, Rowcliffe *et al.* 1995), so an accurate estimate of the number of waterfowl using a field can be obtained.

Ten permanent plots, marked with small wooden stakes, were established on each field. Transects were setup at 305m from one corner of the study field to the other and 10 flags were placed at 30.5m distance from each other along the transect. From each flag a 25cm bamboo

marker was placed 3m from the flag. The bamboo marker acted as the centre marker for the study plots. The position of the marker at each flag was alternated between sides of the transect. We ensured that each end of the transect (flags 1 and 10) were at least 30.5m from the corner or any edge boundary of the study fields. Fields were monitored weekly and fecal pellets were counted in a 1.03m² circle at each permanent plot. The total surveyed area of each field was 10.3m². Fecal pellets were identified as dabbler/goose or swan. Once counted, fecal pellets were removed from the sample plots to avoid recounting at a later date. Swan pellets were encountered so infrequently that they were excluded from the analysis.

Vegetation sward height was measured at four points in each of the ten plots. The percentage cover of all vegetation in each sample plot was estimated visually as an index of biomass depletion. Vegetation measurements were recorded every four weeks. Monitoring continued until late April 2010, when the majority of waterfowl migrate north.

Statistical Analysis

We totaled pellets per acre accumulated on each field over the entire study. We then compared pellet counts between the 5 crop types using a one-way ANOVA test, followed by a multiple comparison using Tukey's HSD test. Statistical comparisons were considered significantly different when $\alpha \leq 0.05$. We totaled all waterfowl pellets counted on each individual winter wheat field and conducted a linear regression against Julian planting date to determine how planting date affected the number of waterfowl supported.

The count data was combined with known waterfowl defecation rates to calculate waterfowl-use days. A waterfowl use day is one duck, goose, or swan using an area for one day. Waterfowl-use days can be used to express the absolute number of animals an area supports over a given time period, regardless of how variably the area is used (e.g. 1000 ducks using a field for 4 days would be the same as 4,000 ducks using a field for 1 day: 4,000 waterfowl-use days).

Waterfowl-use days were compared between treatments to determine how the planting date of winter wheat affects the carrying capacity per unit area of a cereal lure crop. The carrying capacity of the perennial forage treatments was used as an estimate of how many waterfowl use days need to be supported by lure crops. Combining this estimate with the measured carrying capacity of the cereal lure crops allows for recommendations to be made on the acreage of lure crops required to offset grazing on perennial forage crops.

Vegetation height and percent ground cover were compared across crop types to describe patterns of vegetation depletion and assess soil cover. Comparisons of vegetation height and percent ground cover were conducted for October 2009 and April 2010. A one-way ANOVA followed Tukey's HSD was used to determine which crop types differed significantly from one-another. Statistical comparisons were considered significantly different when $\alpha \leq 0.05$.

Results

Waterfowl Use of Cereals and Perennial Forage

There was a significant negative relationship between Julian day planting date and the total number of waterfowl pellets accumulated on winter wheat fields during the study ($F=29.63$; $df=1,8$; $P=0.0006$; Figure 14). There was a significant difference between mean total waterfowl pellets when compared by crop type ($F=11.34$; $df=4,22$; $P=0.0001$). No significant difference in mean waterfowl pellets was observed between Perennial Forage, Winter Wheat late Aug and Winter Wheat Mid Sept. However we did observe a significant difference in the mean foraging between Perennial Forage/Winter Wheat Late Aug and Winter Wheat Late Sept/Spring Cereal (Figure 15).

Figure 16 shows the chronology of waterfowl use of the different crop types during the study. Use of Winter Wheat Mid Sept and Winter Wheat Late Sept began in the first week of November, with use of the former accelerating in the third week of November. Waterfowl began using Winter Wheat Late Aug and Perennial Forage in the last weeks of November, and use of these fields accelerated during December. Waterfowl use of these crop types appeared to decelerate during late December and early January. In early February, waterfowl use of Perennial Forage began to accelerate and use of this crop type continued until mid April.

Vegetation Characteristics

Vegetation height varied by crop type in October 2009 ($F=3.21$; $df=4,17$; $p=0.039$), though the multiple comparison was unable to identify significant differences between the 5 crop categories (Figure 17). Percent cover differed significantly in October 2009 ($F=11.13$; $df=4,17$; $p<0.0001$), with percent ground cover being lowest on Winter Wheat late Sept (Figure 18). Winter Wheat Late Aug and Spring Cereals both provided over 70% ground cover (Figure 18). In April 2010, vegetation height differed significantly between crop types ($F=6.68$; $df=4,22$; $p=0.001$). Perennial forage was significantly taller than all other crop types, except for Winter Wheat Late Aug. All of the cereal cover crops height was below 5 cm in April 2010 (Figure 19). Percent cover differed significantly in April 2010 ($F=12.32$; $df=4,22$; $p<0.0001$). Spring cereals and Winter Wheat Late Aug provided 40-50% ground cover, whereas the other winter wheat treatments provided less than 10% ground cover (Figure 20).

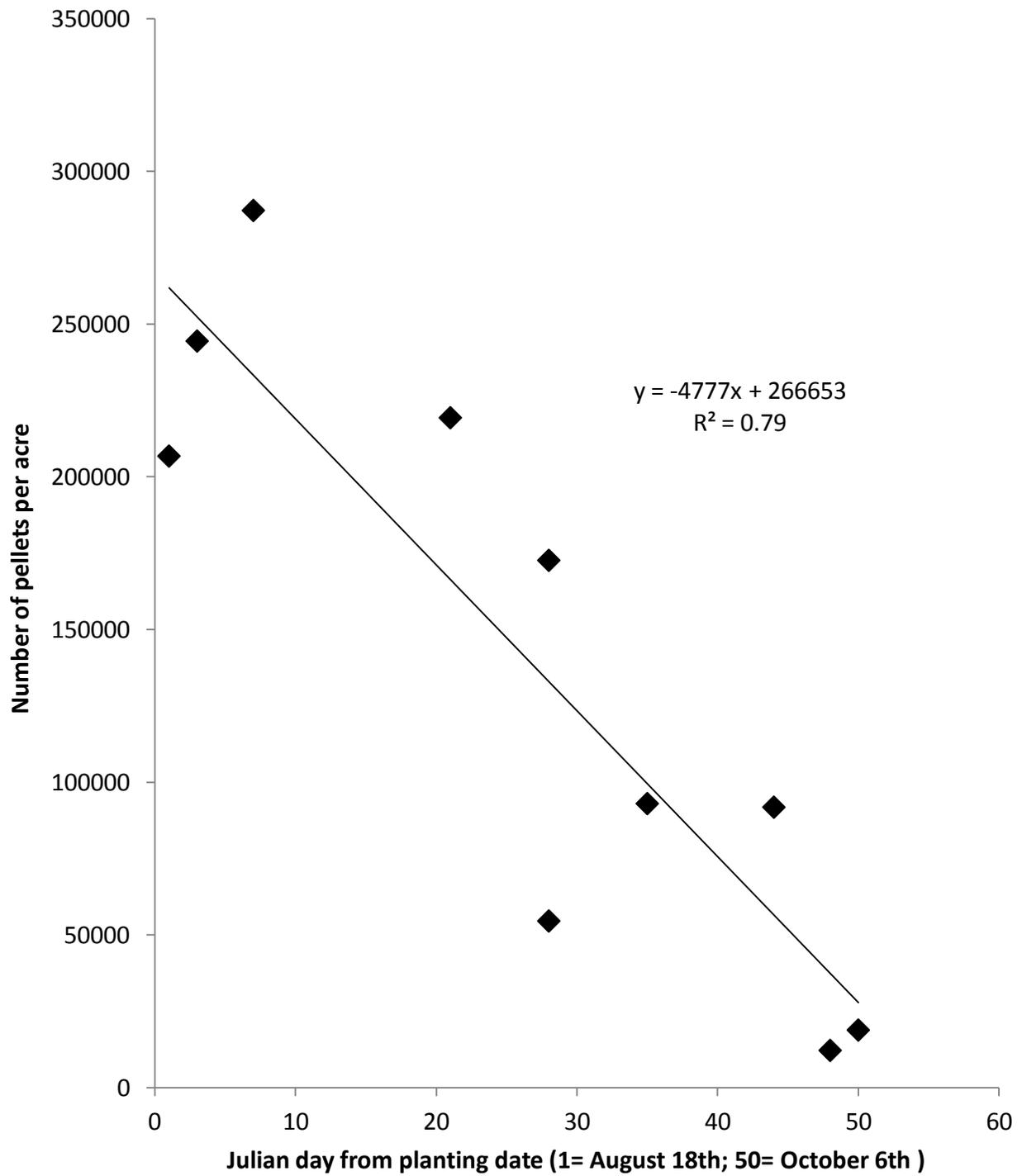


Figure 14. Waterfowl pellets per acre compared to winter wheat planting date. (F=29.63; f=1,8; P=0.0006)

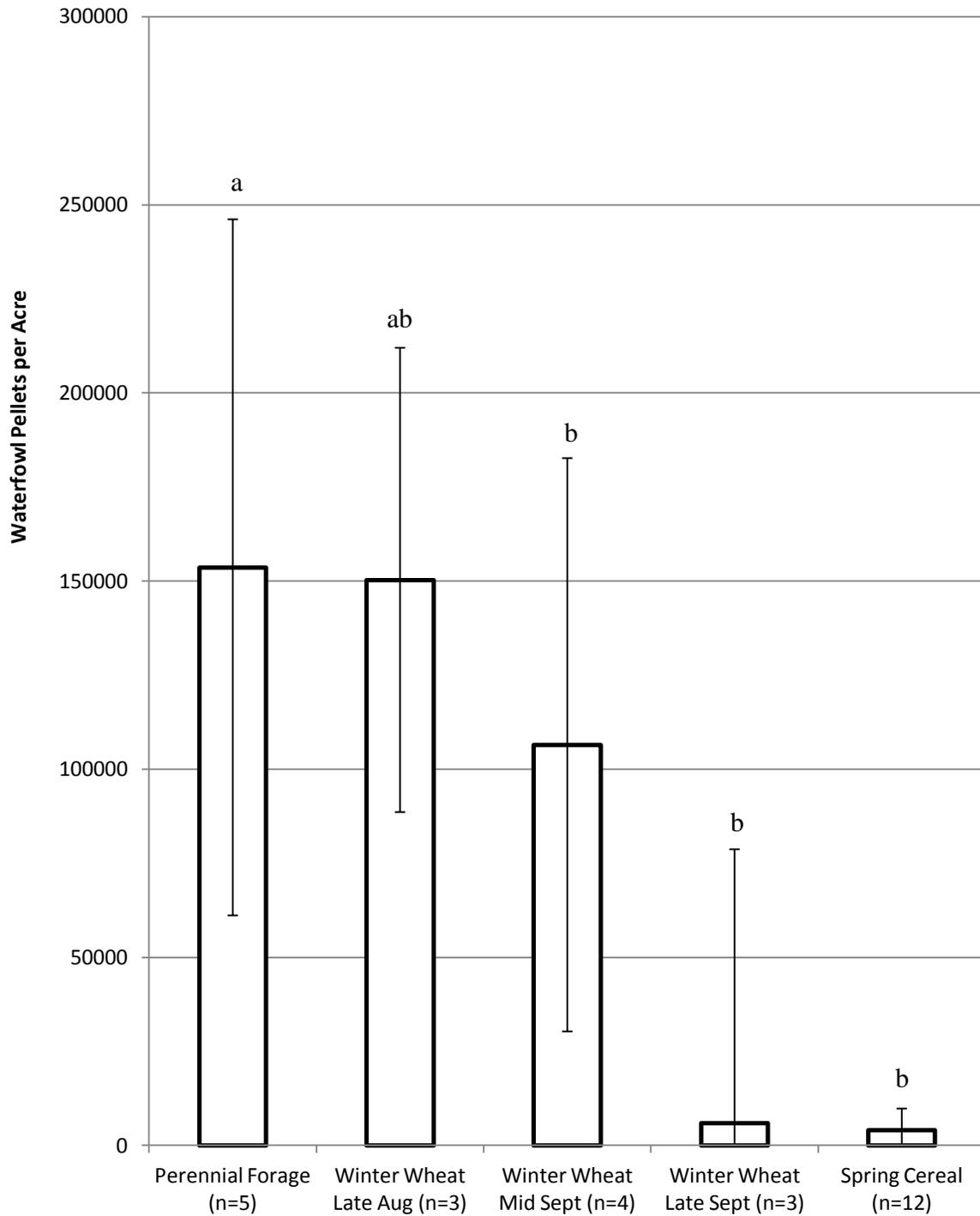


Figure 15. Total number of waterfowl fecal pellets per acre accumulated during study and averaged by crop type, including standard error bars. Columns with the same letter do not differ significantly ($\alpha=0.05$).

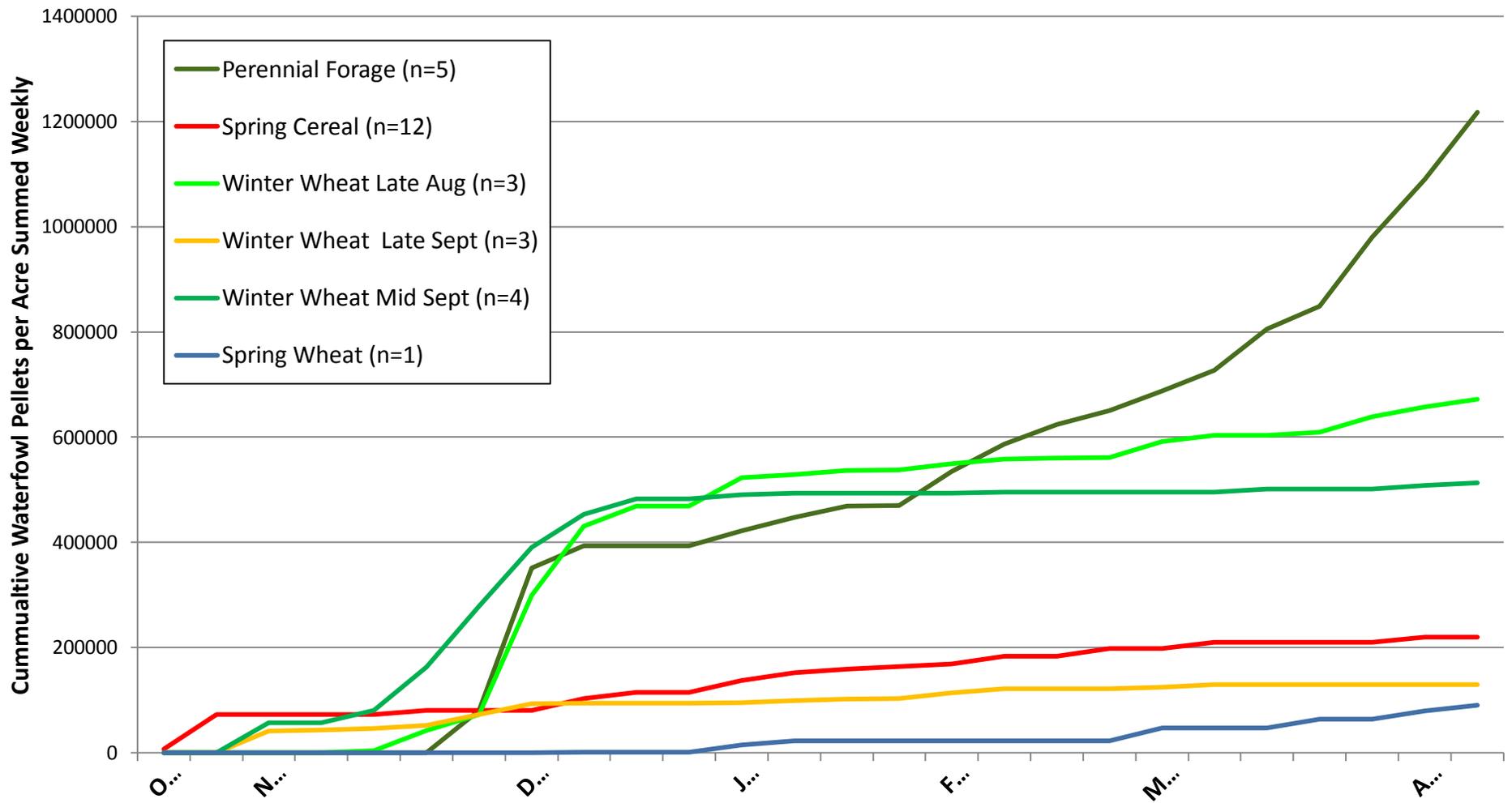


Figure 16. Weekly accumulation of waterfowl fecal pellets per acre, averaged by crop type and summed cumulatively. Weekly counts were conducted between 19 October 2009 to 14 April 2010.

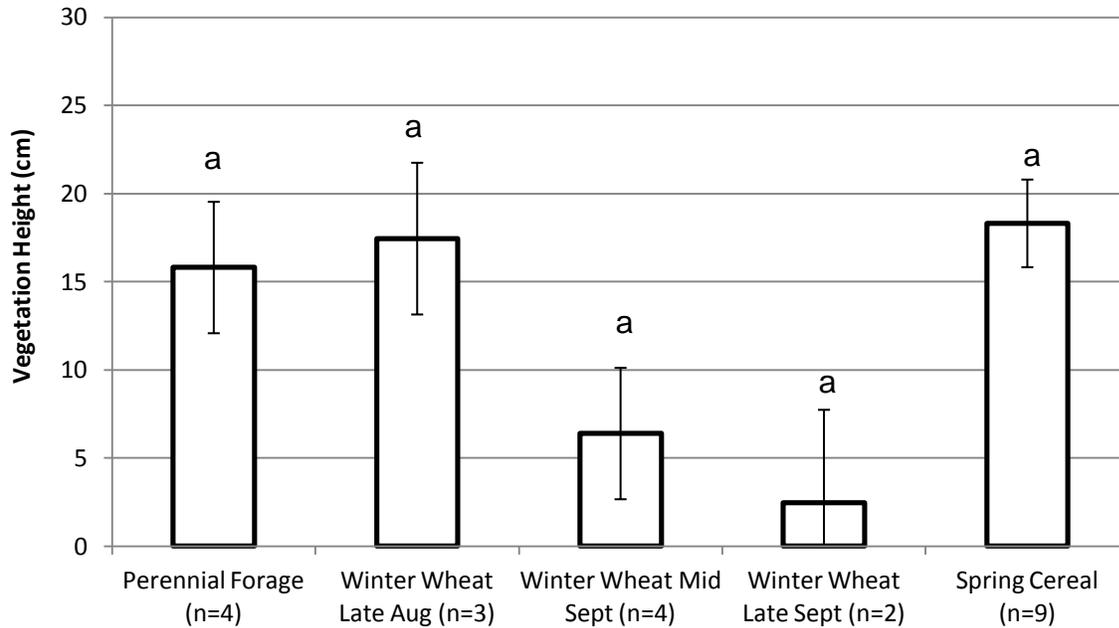


Figure 17. Comparison of mean vegetation height, with standard error bars, of perennial forage, spring cereals, winter wheat in October 2009. Columns with the same letter do not differ significantly ($\alpha=0.05$).

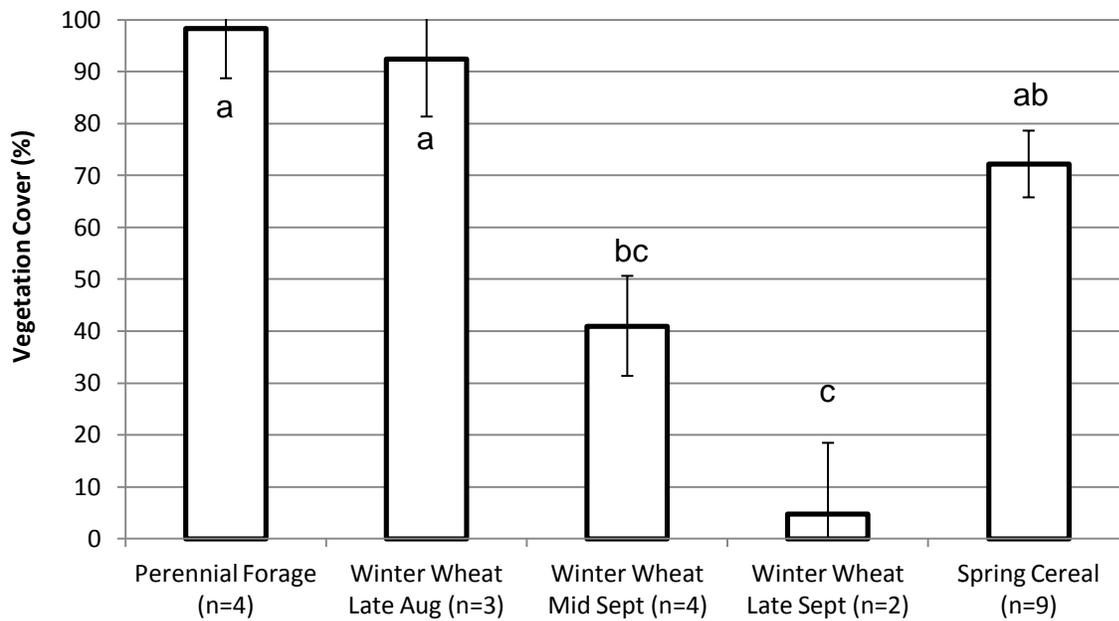


Figure 18. Comparison of percent vegetation cover, with standard error bars, of perennial forage, spring cereals, winter wheat in October 2009. Columns with the same letter do not differ significantly ($\alpha=0.05$).

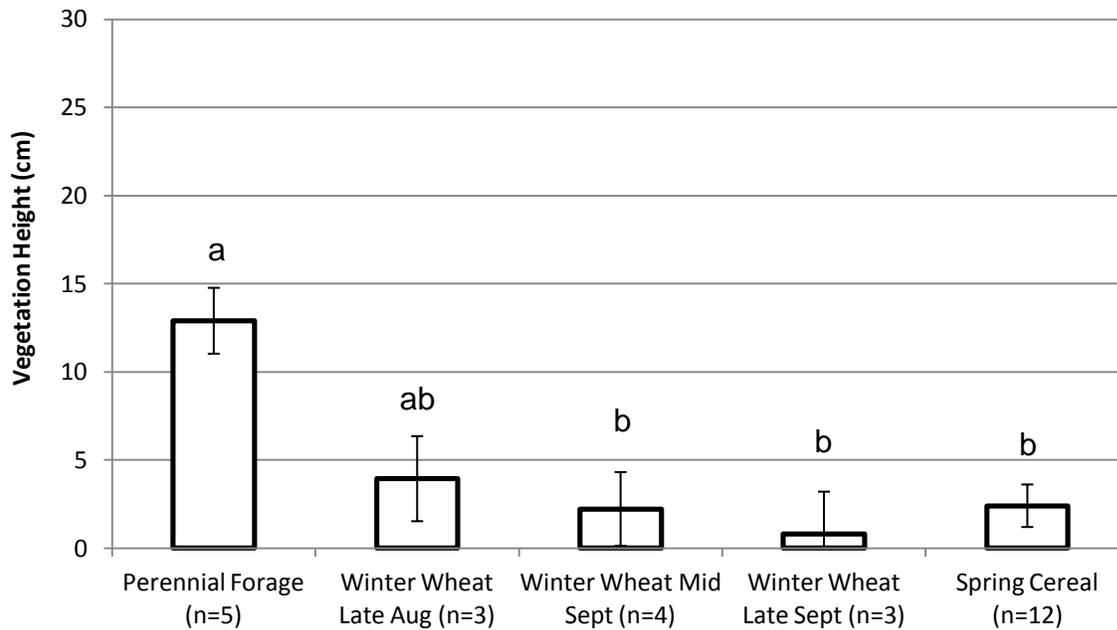


Figure 19. Comparison of mean vegetation height, with standard error bars, of perennial forage, spring cereals, winter wheat in April 2010. Columns with the same letter do not differ significantly ($\alpha=0.05$).

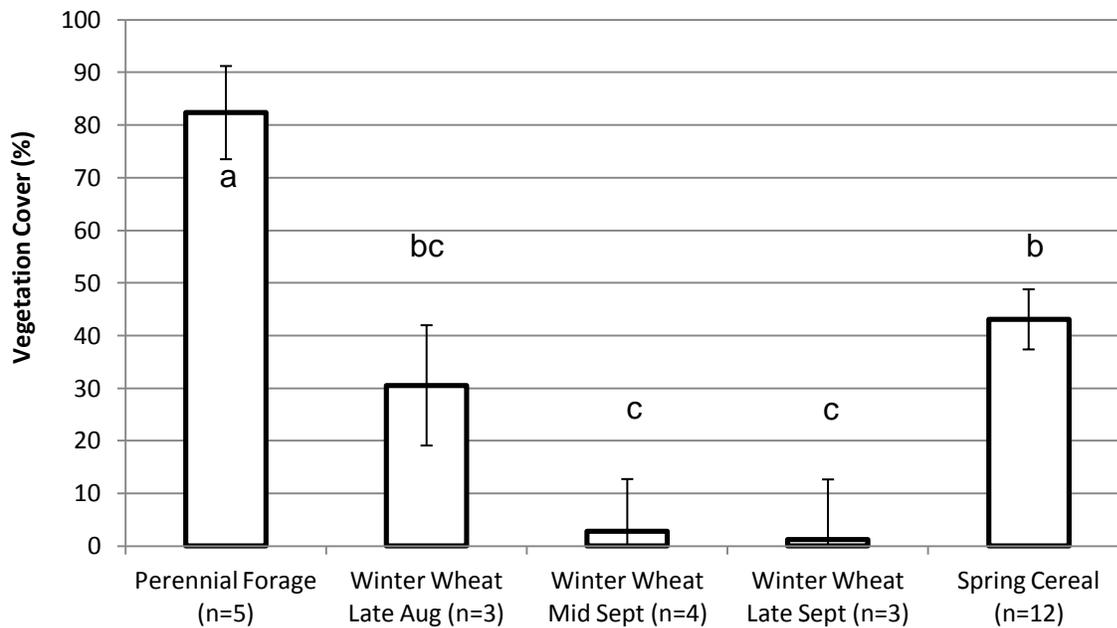


Figure 20. Comparison of percent vegetation cover, with standard error bars, of perennial forage, spring cereals, winter wheat in April 2010. Columns with the same letter do not differ significantly ($\alpha=0.05$).

Discussion

Patterns of Waterfowl Field Use

The winter wheat planted in late August supported the greatest densities of waterfowl; the capacity of winter wheat to support waterfowl declined with later planting dates. There was no significant difference in the number of waterfowl supported by winter wheat planted in late August and perennial forage, but both of these crop types supported significantly more waterfowl than spring cereals and winter wheat planted in late September.

Migratory waterfowl began using farm fields in mid-October. During this time waterfowl fed on spring cereals, late-August planted winter wheat, and late-September planted winter wheat. More intense use of farm fields began in early November, when waterfowl began using mid-September planted winter wheat. A week later, use of late-August planted winter wheat increased, followed the week after by intensified use of perennial forage. Perennial forage, late-August planted winter wheat, and mid-September planted winter wheat were used concurrently by waterfowl into early December.

Use of all crops declined in December when Snow Geese travelled to the Skagit River delta. This movement pattern is observed annually between late December and January (Boyd 1995). During this time, dabbling ducks continued to use late-August and mid-September winter wheat, as well as perennial forage. Perennial forage use increased in March when Snow Geese returned from the Skagit River delta. The use of early-planted winter wheat cover crops in March was marginal compared to perennial forage crops.

In contrast to a study of Snow Geese conducted in 2005 that demonstrated a shift from cover crops to perennial forage (Bradbeer 2007), winter wheat and perennial forage were used concurrently during this study. Cereal cover crops planted as lure crops during this study did not fully abate grazing to perennial forage by ducks and geese. However, cover crops likely offset a portion of the grazing. March and April remains a time when perennial forage grasses are heavily grazed by waterfowl, especially Snow Geese. Additionally, we found that winter cereals planted in late August supported significantly more waterfowl than spring cereals. Spring cereals do not appear to support large numbers of waterfowl because they winter kill; most of the spring cereal vegetation was dead by December.

Planting winter wheat in late September resulted in vegetation cover that was almost completely removed by grazing waterfowl. Winter wheat planted in late September was used significantly less than the earlier planted winter wheat. It is likely that the winter wheat planted in late September did not have enough time to grow tall enough to withstand grazing by waterfowl. Thus, winter wheat planted past late September is likely unsuitable for sustaining a full winter season of waterfowl grazing. In addition, late planted winter wheat probably has little benefit to soil conservation since most of the available vegetative cover is grazed to the ground, leaving very little plant residue to protect the soil from rain erosion.

Unfortunately all three winter wheat treatments planted in late August (WWE) did not appear to provide considerable feed for waterfowl in March and April. However, there was some use of early-planted winter wheat in March that likely offset grazing damage to perennial forage. Interestingly, we included a single replicate of spring wheat in the study and it was used in March. Spring wheat is similar to winter wheat since it is frost tolerant. This was one of the only cover crops to retain some vegetation into spring and as a result it may show promise as a cover crop that lures grazing waterfowl in March when forage is intensively grazed by Snow

Geese. However, this conclusion cannot be confirmed because there was only one spring wheat replicate.

Winter cover crops have the potential to protect the soil from rain erosion throughout the winter, provided they have enough vegetation to cover the soil. Planting winter wheat in late August can increase the amount of ground cover available to protect the soil from heavy winter rains. The cover provided by August-planted winter wheat was statistically similar to that provided by spring cereals. Winter wheat planted in mid and late September does not appear to provide abundant soil cover into April. However, the root systems of cover crops planted in September and October may provide some benefit in the form of increased soil organic matter. It is important to recognize that although the spring cereal cover crops did not provide appreciable feed to waterfowl, they did provide the greatest amount of soil cover into April. Spring cereals remain an important component of winter cover crop planting because of their ability to protect soil surface structure from rain erosion and their ability to provide dead mulch which farmers can incorporate into their soil to increase organic matter content.

Waterfowl Carrying Capacity of Cereals

Using the data collected during this project, we estimated the total number of “waterfowl use days” (1 waterfowl for 24 hours) supported by winter wheat cover crops and perennial forage fields on Westham Island during the 2009/10 study. The linear equation derived for winter wheat (which calculates the theoretical number of waterfowl pellets accumulated per acre) was used to estimate the total pellets accumulated on winter wheat of various planting dates and multiplied by 240 acres (the total area of winter wheat on Westham Island). The carrying capacity of perennial forage was estimated using the average number of waterfowl pellets accumulated during the study and multiplied by 217 acres (the total area of perennial forage on Westham Island).

We assumed that waterfowl defecate every 3.5 minutes (based on 3.1 minutes for Wigeon (Mayhew 1988) and 3-4 minutes for wild geese (Bédard and Gauthier 1986, Rowcliffe *et al.* 1995)) and multiplied pellet estimates by 3.5 to get an estimate of total waterfowl “minutes” spent on each crop type. Based on these estimations, we conclude that the 240 acres of winter wheat on Westham Island supported approximately 78,600 waterfowl use days (an average of 330 waterfowl use days/acre) and 217 acres of perennial forage supported 142,000 waterfowl use days (an average of 650 waterfowl use days/acre).

It is important to note that winter cover crops cannot be completely effective at luring waterfowl from perennial forage fields. Waterfowl are sensitive to the nutrient content of their food plants, especially nitrogen concentration (Sedinger 1997; Bos *et al.* 2005). As perennial forage grasses begin growing in late winter and early spring, they may become more profitable as feed sources than certain cover crops, and it may be impossible to completely exclude waterfowl from grazing them. Protein is highly concentrated in new spring growth and waterfowl have a physiological requirement for protein to build flight muscle and prepare for breeding (Alisauskas and Ankney 1992). However, continuing to manage cereal cover crops to be effective lures for waterfowl will ensure that a portion of the damage sustained to perennial forage crops is abated.

Management Recommendations

Our data show that winter cover crops cannot completely lure waterfowl away from perennial forage. Based on our estimates of waterfowl carrying capacity, current winter wheat acreage would need to double in order to support the same number of waterfowl as perennial forage does between October and April. However, winter wheat planted in late August and early September can support greater numbers of waterfowl than a later planted crop, reducing the acreage required to offset damage to perennial forage. For instance, 184 acres of farmland on Westham Island were planted to barley and oats. If even half of this acreage (e.g., 90 acres) were planted to winter wheat in late August, it could have supported almost 58,000 more waterfowl use days, offsetting an even greater amount of damage to perennial forage grasses.

Based on the results of this study, the Winter Cover Crop Program administered by DF&WT has been restructured to provide greater cost-share payments to farmers who plant winter wheat (or other winter cereals like fall rye) in late August. Table 1 shows the cost-shares that have been adopted for the 2010/11 program year, with 2009 cost-shares for comparison. Encouraging farmers to plant greater acreages of winter cereals planted in late August (\$55/acre compared to \$50/acre in 2009) and early September (\$50/acre compared to \$45/acre in 2009) is a way of providing greater amounts of feed for migratory waterfowl, maintaining soil cover for longer periods throughout the winter, and offsetting damage to perennial forage. Winter cereals are further encouraged by decreasing the cost-share provided for spring cereals from \$45/acre to \$40/acre.

DF&WT will use the results of other research projects findings to further increase the effectiveness of winter cereals as effective lure crops. The project “Eco-friendly Crop Rotations” being conducted by UBC researchers has evaluated several winter wheat varieties that have shown promise in being able to withstand grazing over conventional varieties (Photo 1, Photographic Appendix). Once these varieties have been fully evaluated by the UBC researchers, DF&WT may adopt guidelines to encourage producers to use them as winter cover crops.

Novel management practices may increase the effectiveness of DF&WT’s Winter Cover Crop Program in alleviating grazing damage to perennial forage. Further to the restructuring of the existing guidelines, DF&WT will be piloting program guidelines in 2010 that will encourage farmers to plant forage grasses and clovers into summer grain crops. Under the new guidelines, farmers can receive \$45/acre (Table 3) for these plantings which essentially function as cover crops after the grain crop has been harvested. Perennial forage grasses have been proven by this study to be attractive to waterfowl in spring and clover under-seeded into a grain crop has already been trialed in small plots by the “Eco-friendly Crop Rotations” project. The clover in the trial appeared to withstand heavy spring grazing by Snow Geese and shows promise as both a cover crop and a lure crop (Photo 2, Photographic Appendix).

Table 1. DF&WT Winter Cover Crop Program cost-share structure for 2009 and new cost-share structure adopted for 2010 based on results of this study.

Cover Crop Type	Cost-share for 2009 Program	New Cost-share for 2010 Program
Frost-sensitive Spring Cereals (barley & oats)	Must be planted before September 15 \$50/acre when planted before August 31 \$45/acre when planted before September 15	Must be planted before September 15 \$40/acre flat rate
Frost-tolerant Winter Cereals (winter wheat, fall rye & spring wheat)	Must be planted before October 9 \$50/acre when planted before August 31 \$45/acre thereafter	Can be planted up to October 9 \$55/acre when planted before August 31; \$50/acre when planted before September 30; \$45/acre thereafter
Annual Ryegrass	Can be planted up to October 9 \$50/acre when planted before August 31; \$45/acre thereafter	Can be planted up to October 9 \$50/acre when planted before August 31; \$45/acre thereafter
Clover (red clover, white clover, etc.) AND/OR Forage Grass (timothy, fescue, orchard grass, etc.)	Must be planted before August 15 Only Timothy eligible when under seeded into grain crop	Must be planted before August 15 Clover and forage grass are eligible when under-seeded into grain crop \$45/acre flat rate MAXIMUM 50 acres per farm; call Program Coordinator to confirm acres Note: new forage plantings enrolled in the Delta Forage Damage Compensation Program are not eligible for the Winter Cover Crop Program
Spring-sown grain that is not harvested	\$50/acre (has to be planted before August 31)	\$45/acre flat rate
Spring-sown grain that is harvested, and spilt grain germinates after harvest	Not eligible for program	Not eligible for program

Encouraging the management of forage grasses and clovers not only benefits waterfowl conservation and perennial forage protection, but also soil management. Under-seeding grass and clover into a grain crop requires less tillage than planting a cover crop in late summer/early fall and the plants have a the summer to establish strong root structures. Because they have longer to establish extensive roots systems, forage grasses and clovers seeded into a grain crop may improve soil structure more effectively than winter cover crops that are completely grazed. Clover can also fix nitrogen and can be of benefit to maintaining agricultural soil fertility. DF&WT will employ the fecal pellet counts and whole-field sampling used in this study

to assess the value of forage and clover cover crops to waterfowl in 2010 and 2011, including their ability to alleviate grazing on perennial forage.

The management strategies being evaluated in this project fit well into the overall regional conservation of Snow Geese on the lower Fraser River delta. Traditionally Snow Geese wintered on foreshore marshes of Sea Island adjacent to the Vancouver International Airport (YVR) but are now hazed in the area to avoid collisions with aircraft and maintain aviation safety. It is arguable that as birds continue to be hazed around YVR and Richmond, grazing on west Delta farmlands will continue.

Snow geese still use areas adjacent to YVR, as well as residential areas in the City of Richmond where they graze turf playing fields and residential lawns. In both instances it is desirable to accommodate Snow Geese in another location, but doing so requires increasing the habitat capacity of the new location. Developing the habitat capacity of west Delta farmland using management practices like planting winter cereals in mid-August is a potential solution because geese are already using farms in the area and have done so consistently for the past 30 years. Accommodating birds may offset unnecessary damage to perennial forage crops on these farms. Adaptive management also lends itself to stakeholder participation; if measurable ecological benefit can be shown for this project (e.g. waterfowl such as Snow Geese can be attracted and accommodated by cereal lure crops), stakeholders such as YVR and the City of Richmond may express interest in funding stewardship activities on west Delta farms.

Future funding requests for the DF&WT's on-farm stewardship programs can be justified based on the measurable ecological and agricultural benefits of cereal crop management. New funding sources for adaptive stewardship programs offered by DF&WT are possible if it can be shown that waterfowl can be accommodated on west Delta farms by changing cereal crop management practices. The results provide a comprehensive understanding of how cereal crop management can influence the conservation value of agricultural lands while ameliorating the conflict that arises between farmers and waterfowl when perennial forage is grazed. This kind of information is crucial as land managers assess how to accommodate agriculture and wildlife in an increasingly urbanized and developed landscape.

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Appendix 1: 2010 Cover Crops Fact Sheet and Program Guidelines

Purpose of the Winter Cover Crop Program

Cover crops consisting of grasses, legumes and/or grain crops are grown between annually planted cash crops for the purpose of protecting and enhancing the soil. The most common cover crops in Delta are late summer- or fall-seeded wheat or barley. Other cover crop options include ryegrass and other perennial forage crops, oats or clover.

There are many agronomic advantages of using cover crops. For instance, they can:

- **reduce soil loss due to water erosion;**
- **maintain soil surface infiltration;**
- **improve soil tilth;**
- **provide valuable organic matter to the soil when ploughed down in the spring; and**
- **scavenge nutrients that otherwise may leach from the field.**

In Delta, cover crops also provide feeding habitat to large numbers of over-wintering waterfowl such as Snow Geese, Trumpeter Swans, American Wigeon, Mallards, and Northern Pintail.

Growers are challenged to develop farm management strategies that integrate or reduce the impact of intense waterfowl grazing on winter cover crops and perennial forage fields, particularly from

Wigeon. Cover crops, when carefully planned and seeded, can withstand or recover from repeated grazing events *and* act as effective lure crops to draw waterfowl away from perennial forage fields.

The benefits of soil conservation/improvement and wildlife habitat values combined with typically mild winters make cover crops particularly suitable for Delta farms. This document provides details on cover crop seeding rates and methods, subsequent management practices and cost share information for farmers operating in Delta. If you are interested in establishing cover crops under our program please, carefully read through this document.

Planting a winter cover crop is a cost effective method of providing winter cover to cash crop fields when they are planted well. The type of cash crop and time of cash crop harvest are important factors in deciding which cover crop variety to use and how to plant it. Many planting techniques and cover crop varieties can be used to achieve benefits for both soil and wildlife conservation. *Carefully read the following guidelines and requirements to ensure that a successful cover crop is planted and that you remain eligible for a cost share under our program.*

Winter Cover Crop

Delta Farmland and Wildlife Trust, in collaboration with the University of British Columbia, conducted cover crop screening trials and continues to monitor cover crop management practices in Delta. Many different types of cover crops have been evaluated and Table 1 presents cover crop planting date and seeding recommendations based on best field results.

TABLE 1. COVER CROP SEEDING RATE RECOMMENDATIONS			
PLANTING DATES:	Before Aug. 31	Between Sept. 1 and Sept. 15	After Sept. 15
Minimum* Seeding Rates (lbs/ac)			
COVER CROP VARIETY			
Spring Barley	100	125	**
Oats	100	125	**
Spring Wheat “Max”	100	125	135***
Fall Rye	100	125	135***
Annual Ryegrass “Aubode”	20	25	30
Winter Wheat “Monopol”	100	125	135

* these are minimum seeding rates, higher rates are recommended if broadcast, particularly late in the season
 ** not recommended after Sept 15th
 *** best crops to plant in late fall in areas likely to be heavily grazed by waterfowl

Timing: The earlier a cover crop is established, the greater its soil and wildlife conservation benefits will be. A well established cover crop by mid September will provide excellent soil cover and may withstand or recover from repeated waterfowl grazing events over the winter. *Ideally, the cover crop should be seeded either before (relay cropping in corn, underseeding grain or pea crops, or broadcast several days before digging potatoes) or immediately following cash crop harvest.* Growers may wish to try underseeding an early-planted spring cereal or pea crop with clover, leaving an established cover crop after the harvest. Cover crops can also be relay cropped with silage or sweet corn. Italian ryegrass (Tetron) has been shown to provide excellent results here in Delta.

If the cover crop is planted after a late harvested crop, seed should be drilled if possible and/or applied at a higher rate. Cover crops seeded in early October or into poorly structured or drained soil will have little capacity to provide good soil cover or to recover after grazing. Appropriate cover crop varieties can be seeded up to October 9 under our program.

Drainage: Prevention of standing water on fields through good drainage management practices will not only promote better productivity for most cash crops, it will also encourage the best possible winter cover crop. Although not an absolute requirement of the cover crop program, farmers should attempt to improve soil drainage or level fields to prevent winter water ponding. Cost share funding for field laser leveling is available from our office. Please contact us for more details if you are interested.

Seeding Methods: Although we recommend that only a minimal amount of soil preparation for cover crop establishment be practiced at all times, adequate soil cover for seed is necessary to promote good germination and growth. A flat and rough or “open” seedbed is all that is required for cover crop establishment.

If cover crop seed is *broadcast* after cash crop harvest then the seed must at least be lightly disced in for good soil cover. This *is necessary* for both vegetable and grain crops. More intensive soil preparation such as light tillage, subsoiling or mulching can be done, but is not absolutely necessary. **Do not** subsoil more than 5 days after seeding your cover crop as this could negatively impact cover crop growth. Seed that is broadcast late in the season should be spread at a higher rate.

The preferred seeding method is drilling. By drilling cover crop seed soil contact is assured, and in most cases no additional soil preparation is needed. Grain stubble or standing corn stalks provide some soil surface protection and valuable habitat for wildlife over the winter and it may not be necessary to plant a cover crop in such fields. Growers who are interested in planting a cover crop into stubble should do so with the least amount of soil

disturbance as possible (e.g., a light discing or no-till seed drills).

Relay cropping Italian ryegrass in corn can be done by planting seed between corn rows using a no-till drill. These relay crops can further benefit the environment by significantly reducing the amount of nitrogen lost through leaching or to the atmosphere by absorbing it after corn is harvested.

Nutrient and Management Considerations: For growers who wish to have early spring access to their land for planting cash crops, we recommend a spring cereal cover crop which will die down over the winter, such as spring barley or oats, planted by the end of August. These crops are often winter killed and will release nutrients early in the spring when they can be used by the subsequent crop.

For later planted cover crops, winter wheat may also be an option. Because of its relatively slower and shorter growing characteristics, winter wheat can be plowed down in the spring relatively easily, provided the grower does so as early in the year as possible. Winter cereals may require additional discing or mowing in the spring in order to chop the crop and make it easier to incorporate.

Winter Cereal Production: For growers who are seriously thinking about taking their fall planted winter wheat to grain, we recommend that planting occur close to the second week of September, seeded at approximately 125 lbs/ac. The use of “certified” seed is recommended and the variety “Monopol” is one that has been shown to be quite successful in Delta.

Cover Crops Planted After Grain Harvest: Certain conditions apply when planting a cover crop after a grain crop. When a grain crop has been harvested, seed spilt/blown from the combine is NOT eligible as a cover crop. Grain that has been planted but not harvested is an eligible cover crop.

Cover Cropping Program: Growers in Delta can participate in the DF&WT cover cropping program by planting any of the crops listed in Table 1, in addition to well-established clover. Only winter cover crops that are seeded after a cash crop is removed are eligible. After verification of acreage, co-operators will be reimbursed up to \$50/acre of cover crop planted before August 31st and up to \$45/acre thereafter. There is no limit to the number of acres for which a co-operator can apply. The planting deadline for spring cereals (oats and spring barley) is September 15 and for winter cereals (spring wheat, fall rye, annual ryegrass and winter wheat) the planting deadline is October 9. Planting agreements must arrive at the DF&WT office by October 19 for this year. DF&WT Cover Crop Program Planting Agreements and additional information are available at the DF&WT office. If you have any questions or concerns, please contact our office.

Appendix 2: Greenfields Project Cover Crop Program Evaluation Survey Questions

1. Has the quality of soil improved on cover cropped fields compared to fields not cover cropped?
2. What do you believe are the best management practices for cover cropping?
 - drilled vs. broadcast
 - overwintering vs. mulched
 - seeding rate, planting date, cleaned vs. uncleaned seed
 - certified vs. uncertified seed?
3. What method do you believe brings the best results for the least effort and expense?
4. What type of cover crop (i.e. which crop species, mulch vs. overwintering etc.) provides the most benefit to: soil conservation or wildlife habitat?
5. Does the Greenfields Project allow for the best management practices?
6. What are the limiting factors to planting cover crops on the farm (i.e. availability of seed, cost of seed, changes in crop rotations, availability of time, etc.)?
7. With respect to fields that are grazed or ungrazed, what limits the overwintering survival of cover crops?
8. Are there lost opportunities for other types of cash crops due to waterfowl grazing? If so, what crops?
9. In your opinion, have cover crops had any detrimental effect on subsequent cash crops (i.e. weed control, disease control, increased tillage, etc.)?
10. Are there any benefits to planting cover crops in October? What should the latest planting date(s) for cover crops (overwintering vs. mulched etc.) be? Why?
11. Are the following measures adequately addressing the issue of crop damage by grazing waterfowl:
 - irrigation water from east Delta
 - cost-sharing programs for laser leveling
 - first year grassland set-aside
12. Have crop and soil management practices changed as a result of the Greenfields Project?
 - if so, in what way and to what extent?
 - if not, why not?

13. What in general are the economic benefits to farmers in planting winter cover?
14. Are there other benefits to planting cover crops?
15. What is the cost of not cover cropping? If financial incentives were not provided, would you continue the Project anyway?
16. Are there any other costs associated with cover cropping aside from the cost of establishment?

Appendix 3: Summary of Available Cover Crop Data

year	Crop	acres	Planting date	<u>November</u>			<u>December</u>			<u>January</u>			<u>March</u>			Fall use/grazing	Spring use/grazing
				Crop height	Crop cover	Grazing	Crop height	Crop cover	Grazing	Crop height	Crop cover	Grazing	Crop height	Crop cover	Grazing		
1990	Y	Y	Y														
1991	Y	Y	Y														
1992	Y	Y	Y												X		
1993	Y	Y	Y												X	X	
1994	Y	Y	Y												X	X	
1995	Y	Y	Y												X	X	
1996	Y	Y	Y												X	X	
1997	Y	Y	Y												X	X	
1998	Y	Y															
1999	Y	Y	Y				Y	Y	Y†		Y	Y†	Y	Y	Y†		
2000	Y	Y	Y				Y	Y	Y†		Y	Y†	Y	Y	Y†		
2001	Y	Y	Y				Y	Y	Y†	Y	Y	Y†	Y	Y	Y†		
2002	Y	Y	Y														
2003	Y	Y	Y														
2004	Y	Y	Y														
2005	Y	Y	Y						Y			Y			Y		
2006	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
2007	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		
2008	Y	Y	Y	Y	Y	Y	Y	Y	Y								

X = Between 1992-1997 grazing was measured as a percentage of the field area taken at two time points in the year. However, grazing intensity was not recorded on a scale that can be compared across fields or years. Instead, intensity was recorded to indicate if a particular field had greater or less damage from the beginning to the end of the year (e.g., relative damage within that field). **Y** = Between 1999 and 2001 grazing data was collected on a 0-4 scale, where 1 = 1-25, 2 = 26-50, 3= 51-75, 4= 76-100. This scale was used for % cover (e.g., % crop cover) and as a measure of height. **†** = grazing data from 1999-2001 was measured as heavy or moderate in a 0-4 point scale, while grazing data between 2005-present was measured as the percent of the field that was heavily, moderately or lightly grazed. Recent data can be back calculated from a percent to a 0-4 point scale to allow for comparisons. However, because recent data was measured as heavy, moderate or light, the back calculation still does not match up with the heavy or moderate data previously collected.