PLANT SPECIES ABUNDANCE, DIVERSITY AND SOIL QUALITY OF GRASSLAND SET-ASIDES ON THE FRASER RIVER DELTA.

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Abstract

This project included the monitoring and evaluation of a sample of set-asides enrolled in the Delta Farmland and Wildlife Trust's Grassland Set-aside Program. The Set-aside program is one of several farmland stewardship programs in the Fraser River Delta of British Columbia and its objectives include soil conservation and wildlife habitat creation.

Vegetative characteristics and soil quality were studied at both small plot and multi-field levels on sites enrolled in the Delta Farmland and Wildlife Trust's Grassland Set-aside Program. At the small plot site, the effects of a manure application and two nurse crops (barley and annual ryegrass) on plant canopy characteristics and soil quality of a grassland set-aside seed mix were compared to a control (no manure or nurse crop). Indices for measuring vegetative characteristics included plant species abundance (Braun-Blanquet Cover-abundance Scale, species frequency and biomass), species richness (number of species found on a site) and species diversity (average number of species per quadrat). For the small plot site, the main soil quality indicators included mean weight diameter (MWD) and water stable aggregates (WSA), while at the multi-field level soil pH, electrical conductivity (EC) and sodium adsorption ratio (SAR) were more relevant.

At the small plot study, between May and August of 1998, weeds were most effectively suppressed by barley>annual ryegrass>no nurse. Similarly, the biomass of the seeded species was suppressed in the order barley≥annual ryegrass≥no nurse. No significant effect of the nurse crop was found on the abundance of seeded species beyond the fall of 1998. There was no significant effect of either nurse crop treatment or establishment of the grass stand on MWD or WSA. The manure application significantly increased the total and

the seeded species biomass ($p=0.1$). Cover by orchard grass (*Dactylis glomerata*) was significantly higher and cover by short fescues (*Festuca rubra spp.*) was significantly lower with manure application. A correlation analysis between biomass and percent cover across all nurse crop and fertility treatments over two years showed that cover and biomass were significantly and positively correlated.

At the multi-field level, a regression analysis between percent cover and pH and EC was significant for timothy, short fescue and the seeded species as a group ($p \leq 0.1$). EC was found to have a greater effect than pH in four of five analyses. As a set-aside matured, species richness remained relatively stable, biomass peaked then stabilized, species diversity decreased and plant-litter accumulated. Variation among sites was high due to uncontrollable factors such as time and method of seeding, weather conditions during germination, fertilizer regimes, soil quality and site history.

Results from this study indicate that...

1. The farmer's choice of nurse crop does affect total cover and biomass in the first summer of a set-aside, but is unlikely to affect soil quality or vegetation characteristics of the set-aside after the establishment year.
2. Measures of cover using a Braun-Blanquet cover-abundance scale give similar results as biomass measures.
3. Soil factors most likely to limit successful establishment of the set-aside mix rank as follows; salinity≥water problems>low pH.
4. A grassland set-aside is not able to remediate severely degraded soils where an existing soil drainage problem is not corrected before establishment.

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Acknowledgements

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Chapter 1 BACKGROUND

1.1. Introduction and History of Agriculture in Delta

Despite visits to the coast of Southern British Columbia by Spanish explorers as early as 1790, Captain Vancouver in 1792 and Simon Fraser in 1808, European settlers did not actually arrive in what is known today as Delta until December of 1824 (Taylor, 1958). Even still, the settlement of Delta did not begin until the goldrush of the Fraser River in 1858. By 1877, most of the lowlands of Delta, except the peat bog, were privately owned (Taylor, 1958). Early agriculture was subsistent and land parcels were large. It was not until 1892, when Delta was included in the Annual Reports of the British Columbia Department of Agriculture, that Delta began to be recognized as an agricultural production area. In 1898, the farmers of Delta formed the Delta Farmer's Institute (DFI).

The farmland in Delta has an inherent high capability for agriculture. Due to a favorable climate, flat topography and deep silty soils, Delta presently ranks among the top 20% of land most suited for agriculture in the province of British Columbia (Leonoff et al., 1992). Other factors that make Delta an ideal place for agricultural production include its proximity to the Vancouver market and a strong farming community of experienced and knowledgeable producers.

Land tenure is an issue to farming in Delta. A massive government expropriation in 1968 and the subsequent land use speculation resulted in Government and the private sector (other than farmers) owning as much as 67% of the farmland in Delta's ALR (Statistics Canada, 1996 census of agriculture). Almost all of this land has been worked by tenant farmers holding relatively short lease agreements with high rents. Maximizing returns has resulted in many fields devoted to cash crops, leaving fields bare over winter and returning little, if any, organic matter to the soil. Due to their moderately fine texture and naturally high water tables, the soils of Delta are inherently sensitive to many agricultural practices. Farmers' concerns regarding soil degradation in Delta have been well documented in the Delta Agricultural Study (Leonoff et al., 1992) and are attributed to poor drainage, waterfowl traffic during winter months, heavy farm equipment, bare soils over winter and decreased additions of organic matter to the soil.

1.1.1. Need For Soil Conservation Programs

The decline of soil quality in Delta suggests that current agricultural practices and policy are not sustainable. Issues of soil degradation in Delta must be addressed if Delta's agricultural industry is to remain viable. Soil conservation measures require long term investments of time and money and are not feasible in many situations due to the land tenure situation. There is a need for efficient and effective soil conservation programs that are affordable for both tenant and resident farmers.

Delta provides diverse habitats such as estuarine waters and foreshore, freshwater marshes, upland fields and woodland to a variety of wildlife species. Being on the Pacific Flyway, Delta is host to some 1.5 million migratory birds each year (Norecol et al., 1994). In addition to the migratory bird population, many resident species, including vulnerable species such as the Barn Owl, make use of Delta's habitat. Although farmland does not identically mimic the native grassland vegetation and drainage of the Fraser River delta pre-1850, (North and Teversham, 1984) it offers a variety of habitats as opposed to urban and industrial developments (Delta Farmland and Wildlife Trust, 1994). Further, many negative affects of conventional agricultural practices on wildlife can be addressed with a number of farmland stewardship practices. For example, field margins, hedgerows, riparian and grassland set-asides can be used to simultaneously enhance both wildlife and agriculture.

1.2. The Importance of The Grassland Set-aside Program

Both the United States (US) and the European Community (EC) have land diversion programs with objectives including supply control, diversification, afforestation, grazing, wildlife habitat creation and soil conservation. In the United States, setting aside land has been practiced for about 50 years (Ervin, 1992), while in the EC, it was only introduced in 1988. Economic analyses of the US Conservation Reserve Program (CRP) done in 1985 attributed much of the benefits of CRP to increased wildlife habitat and improved surface water quality. The objectives of the Grassland Set-aside program coordinated by the Delta Farmland and Wildlife Trust (DF&WT) include soil and wildlife conservation, but do not include the reduction of food produced in Delta. When involved in this program a farmer will seed not more than 16 ha (40 acres) of farmland to a pre-selected mix of perennial grasses. The farmer is responsible for maintaining the set-aside so that good grass growth, and hence wildlife habitat, is achieved. Providing this occurs, the farmer receives up to $741/ha ($300/per acre) per year for a period of up to 5 years. The grassland set-aside is one example of how certain stewardship practices can create harmony between wildlife and agriculture in Delta.

1.2.1. Compensation for Farmland as Wildlife Habitat

"Farmland is required by wildlife for habitat, resulting in impacts to the agricultural industry" (Norecol et al., 1994). Since farming began in Delta, farmers have supported wildlife by providing fields for them to roost and crops for them to graze. Soils are damaged under the webbed feet of waterfowl and winter grain and summer forage crops are lost to grazing waterfowl. The Grassland set-aside program provides farmers with compensation for quality wildlife habitat that they provide. The grassland set-aside program also makes it possible for tenant farmers to invest in improvements to soil quality on leased land preventing or remediating such severe soil degradation. At this time, the provincial government and the British Columbia Agriculture Council are finalizing details for a compensation program for dairy farmers whose forage fields have been damaged by waterfowl.

1.2.2. Regeneration and Reclamation of Degraded Soils

According to a 1992 survey of Delta farms, 1/3 have soil quality problems associated with poor structure and low organic matter content (Leonoff et al., 1992). Some parcels of farmland in Delta are degraded to the point that cropping is no longer viable. In order to prevent the spread of abandoned farmland, some feasible means of conservation for working fields and reclamation for those fields that are no longer viable for crop production must be implemented. Hermawan (1995) found that, within the first year, a grass ley crop could significantly increase soil aggregate stability of a severely degraded soil in Delta.

1.2.3. Lost Habitat on Sea Island

In the development of the third runway at the Vancouver International Airport, 179 ha (440 acres) of wildlife habitat was lost (Delta Farmland & Wildlife Trust, 1995). More than half of the habitat lost was hayfield, pasture, and old field. Since grassland set-asides are similar to the habitat lost on Sea Island, the DF&WT's Grassland Set-aside Program may partially offset the habitat that was lost.

1.2.4. Valuable Wildlife Habitat

The grasslands of Delta are used as habitat by many wildlife species. Great blue herons, red-tailed hawks, rough-legged hawks, barn owls and short-eared owls hunt small mammals, passerines and waterfowl found in the grasslands. Waterfowl use grasslands as winter feeding habitat. Savannah sparrows, northern harriers, short-eared owls, ring-necked pheasants nest in grasslands (Delta Farmland and Wildlife Trust, 1994).

1.3. The Vancouver International Airport (YVR) Stewardship Fund

The YVR Stewardship Fund is a perpetual endowment fund held for the DF&WT by the Vancouver Foundation. The initial deed of gift was granted to the DF&WT by Environment Canada in 1995 as part of a larger compensation plan for the loss of wildlife habitat during the expansion of the Vancouver International Airport. The Vancouver Foundation releases earnings on this fund to the DF&WT to coordinate and run farmland stewardship programs on the Fraser River delta.

The long-term goals of the YVR Stewardship Fund Monitoring Program directly related to this research project include improving the ability to evaluate the success of farm stewardship practices as 1) effective wildlife habitat management or enhancement techniques; and as 2) effective means to replace, maintain and/or recreate habitat that benefits species and habitat types affected by the airport expansion on Sea Island.

As this project achieves some of the goals and activities set by the YVR Wildlife Stewardship Fund Long-Term Wildlife Monitoring and Evaluation Work Plan, partial funding has been provided through the Delta Farmland and Wildlife Trust.

Other financial contributors to the DF&WT Set-aside Program include the Delta Agricultural Society and the Delta Farmer's Institute.

Chapter 2 LITERATURE REVIEW

2.1. Soil Quality

When measuring soil quality it is important to choose indicators relative to the management of the soil and land use objectives in mind. The numerous soil quality indicators available are usually categorized as chemical, physical or biological. However, consideration should be given to how sensitive the indicators are to both changes in soil management and seasonal conditions. For this study, indicators needed to be sensitive enough to pick up changes in soil quality by the second season of the set-aside, but not so sensitive that the effect of the set-aside could not be distinguished from uncontrolled factors such as precipitation. Given the magnitude of the study, indicators also needed to be relatively easy and inexpensive to assess. In light of the above, and when consideration was given to the factors that are most likely to limit crop growth in Delta, the selection of soil quality indicators available became significantly smaller. Indicators chosen included mean weight diameter (MWD), percentage of water stable aggregates (WSA), earthworm counts, pH, electrical conductivity (EC), percent organic matter (OM), total nitrogen (N), available phosphorus (P), and exchangeable potassium (K), calcium (Ca), magnesium (Mg) and exchangeable sodium (Na).

2.1.1. Soil Structure

Soil structure is often used to describe a soil's quality and can be defined as the arrangement of sand, silt and clay particles into aggregates (peds). Aggregate stability is the ability of those soil peds to resist destruction. Resilience of peds is a function of soil texture (the proportion of sand, silt and clay), inorganic cementing agents (calcium carbonate, iron & aluminum oxides), organic cementing agents (polysaccharides from microbial and root exudates, root hairs and fungal hyphae, humic substances), and freeze-thaw and wet-dry cycles.

MWD and WSA are measures of aggregate stability. For both measures, a sample of macroaggregates (2-6 mm) from the soil surface is moved up and down through water on a stack of sieves that decrease in mesh size from top to bottom. After washing, each sieve contains a certain size fraction of water stable aggregates. The content of each sieve is dried and weighed. The MWD is calculated as the sum of the mean diameter for each size fraction (sieve) multiplied by the proportion of the total sample. In this calculation, each size fraction is weighted according to its importance - the larger fractions being weighted more heavily. The larger the MWD, the more stable the aggregates are and the better soil structure is. WSA are calculated on the same sample as the proportion of the total sample remaining on the sieve as stable aggregates.

Samples of aggregate stability are relatively easy and inexpensive to process. Aggregate stability changes over the season being weakest in spring after a wet winter and strongest in the driest part of summer. Similarly, aggregate stability will be better after a cold, dry winter than a cool, moist one. When soil type, time of sampling and methods of preparation are similar, aggregate stability can be used to detect changes in soil quality over time.

Karlen et al. (1999) evaluated several indicators for quantifying changes in soil quality before and after enrolling sites into the Conservation Reserve Program (CRP) in the

United States. In this study, aggregate stability detected significant differences in 50% of the data sets and was therefore recommended as a soil quality indicator for evaluation of CRP sites.

2.1.2. Earthworm Counts

As well as being an indication of favorable soil conditions, earthworms can play a significant role in soil aggregation (Harris et al., 1966). They increase the availability of nutrients, incorporate organic matter into the soil, initiate mineralization and humification, improve soil aggregation and porosity (USDA, 1999). Earthworm populations will vary temporally and spatially with tillage and cropping practices, soil organic matter content, moisture and temperature, pH, food supply, season, and vegetative cover (USDA, 1999; Harris et al., 1966). The absence of earthworms may mean that they have not been introduced to an area or it may be an indication of poor soil conditions.

2.1.3. Soil Salinity

Initially, EC and exchangeable sodium were expected to change as a result of set-aside establishment. If a grassland set-aside was the mode of remediating salt affected soils alone it would do so by improving soil structure. Better structure would prevent surface sealing and maintain macropores allowing water to infiltrate and leach salts out of the profile during the rainy season.

Electrical conductivity is the preferred index for measuring soil salinity (Sparks, 1996) because it is reliable, inexpensive and fast. It is a measure of a soil's ability to conduct electricity and is directly related to the amount of dissolved salts in the soil solution. The predominant ions from dissolved salts in acidic saline soils, like those of Delta, are Na^+,

K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, and maybe NO_3^-. Generally soils are not considered to be saline unless the EC of a saturated soil paste is equal to or greater than 4 dS/m.

Soil sodicity is indicated by the percentage of sodium on the cation exchange complex. Sodicity has both direct and indirect effects on soil structure. High sodium levels decrease plant growth and therefore soil organic matter content. Sodium ions are directly responsible for poor soil structure. The sodium ion has a large hydration radius leaving it in the diffuse part of the double layer, increasing the repulsive forces between soil particles (dispersion). As a result, soils with a large proportion of Na^+ on the cation exchange complex have decreased water infiltration, aeration and root penetration (Helmke & Sparks, 1996). While sodium tends to disperse soil colloids, other cations including Ca^{2+} and Mg^{2+} tend to flocculate soil colloids. Therefore, we are interested in the proportion of Na^+ on the cation exchange complex, hence, the calculation for ESP below...

$$\text{Exchangeable Sodium Percentage} = \frac{[\text{Na+ in cmol charge/kg}] \times 100\%}{\text{CEC in cmol charge/kg}}$$

When ESP is greater than 15, soils are classed as sodic and soil structure is adversely affected. The largest source of sodium on earth is seawater. All of the soil series in this study were formed in a marine environment and several are close enough to the coastline that sea water intrusion and atmospheric deposition could still be significant sources of sodium ions. Other common mineral sources of sodium are plagioclase feldspars (ie. albite $NaAlSi_3O_8$) (Helmke & Sparks, 1996) that are deposited by waters draining areas of granite, gabbros, felsites and basalts. The parent materials of the soils in this study are indeed alluvial or glaciomarine deposits. In humid areas, it is uncommon to find sodic soils because the large hydration shell of the sodium ion prevents it from being held strongly in soil. Elevated exchangeable sodium concentrations in humid soils may, however, indicate salt affected soils and poor drainage.

High levels of soluble salts in the soil will adversely affect the growth of the seeded species by weakening or even reversing the osmotic water potential gradient. Subsequently, there will be a loss of turgor pressure and retardation in the extension of growing cells. If levels of sodium are also high, soil colloids are dispersed and structure is degraded resulting in poor infiltration, aeration and drainage.

2.1.4. Soil Acidity

Soil pH affects plant growth via the availability of nutrients, activity of microorganisms and the solubility of aluminum. At various pH levels, plant nutrients bind to and release from soil colloids and other minerals changing their availability. Most nutrients are at maximum availability between a pH of 6 and 7 (USDA, 1999). Generally, the optimal pH range for bacteria in soil is intermediate and higher (ibid.). Fungi have a wider optimal pH range than bacteria (ibid) and tend to dominate biological processes in acid soils such as those in Delta. While fungi play a dominant role in the formation and stability of macroaggregates (Chantigny et al., 1997; Kahn, 1975; Yocom et al., 1985; Schenck et al., 1982), bacteria mediate much of the nutrient cycling and are also involved in aggregate stabilization. The soils of Delta are relatively young thus high concentrations of aluminum are unlikely (pers. comm. Dr. Art Bomke, UBC).

Prevailing factors during soil formation set the starting point for soil acidity. Climate, specifically rainfall and temperature, determines the degree of leaching of calcium and other base cations from a soil. As the process of weathering continues, a soil usually becomes more acidic. The soils of Delta receive sufficient rainfall to leach base cations from the soil. In addition to this, these soils were formed/deposited in marine or fresh-water/marine environments. As a result, sub-soils may be high in pyrite (FeS_2) which is common in marine environments (Thomas, 1996). When sub-soils are exposed to air during ditch cleaning or when soils are drained, pyritic minerals oxidize and H_2SO_4 is formed.

Soil may become more acidic with increasing soil salinity. When levels of soluble salts are high in soils, the neutral salts dissolve into the soil solution resulting in the displacement of Al^{3+} and H^+ by Ca^{2+}, Mg^{2+}, or K^+ on the exchange complex. The result of increased Al^{3+} , aluminum hydroxides and H^+ in the soil solution further reduces the pH. This effect is known as a salt induced decrease in pH. For this reason, pH of salt effected soils is measured using a 0.01M solution of $CaCl_2$ which masks the effect of the salts (Thomas, 1996). If soils are not saline, pH is measured in a solution of distilled water. Similar to EC, soil pH is not expected to change as a result of the establishment of a set-aside, however, unfavorably low pH may affect the success of the seeded species.

2.1.5. Soil Organic Matter

Percent organic matter content is often estimated by determining total organic carbon and multiplying it by a constant that represents the amount of C in organic matter. Total organic carbon changes very slowly and therefore it is not a very sensitive indicator for detecting changes in soil quality due to new management practices (Karlen et al., 1999).

Organic matter can be categorized as transient, temporary or persistent. The transient fraction consists of polysaccharides from microbial and root exudates. The temporary fraction consists of plant roots and fungal hyphae. And the persistent fraction consists of humic substances and other strongly adsorbed polymers. It is the transient or labile fraction that contributes most to aggregate stability (Harris et al., 1966). Measurements of the "active or readily labile" carbon fraction will detect smaller changes (Sikora et al., 1996) and therefore may be a more suitable soil quality indicator.

2.1.6. Other Soil Quality Indicators

The remaining the soil quality indicators (N, P, K, Ca and Mg) were used to indicate whether or not the initial plant nutrient status of the soil might effect the establishment of the seeded species.

2.2. Soil Conservation Effects of Grassland Set-asides

In 1992, soil quality problems reported by Delta farmers included soil salinity, low pH, compaction, low organic matter levels, poor structure and poor drainage (Leonoff et al., 1992). The natural process of soil formation of the Fraser River delta, is responsible for high levels of soluble salts and low pH (Luttmerding, 1981b). Long periods of continuous cultivation for cash cropping on these soils have led to a decline in organic matter levels, poor soil surface structure and deep soil compaction. In addition, the soils are fine textured and elevations are within 0 to 3 m of sea level making them poorly drained due to high water tables. These factors work together to produce a unique cycle of degradation in Delta soils. With persistent cultivation of wet, low-lying areas, soil structure is degraded resulting in poor infiltration and drainage of water. In some soil series, soluble salts from the lower profile move upward with capillary rise and rising winter water tables. Poor structure and surface sealing results in saline water being ponded on the soil surface or trapped in the soil's upper profile. The increase in soil salinity and soil water content results in crop drown-out and colonization by shallow rooted, salt tolerant plant species. If a high level of sodium is present, soil structure is further degraded as sodium ions disperse soil colloids. Areas with ponded water attract dabbling ducks, which aggravates surface sealing further.

Historically, raising cattle and horses on grass pasture was a large part of agriculture in Delta. However, about 40 years ago, grass pasture was given over to cash cropping. A combination of negative effects of the expropriation in 1968 and better transportation and infrastructure made it feasible for the dairy (and beef cattle) industry to move east up the Valley where urban pressures were less and land more affordable. Soon, the majority of agriculture in Delta consisted of processing crops (peas, beans, corn and occasionally, potatoes) and grass had disappeared from the rotation all together. The DF&WT's Grassland Set-aside Program makes adding grass pasture back into the rotation feasible and thereby contributes to soil conservation in the delta.

Specifically, grassland in the rotation conserves soil by providing vegetative cover, which means an increase in soil organic matter and subsequent improvements in soil structure (Carter et al., 1994). Improved soil aggregation, or structure, allows soil to resist surface sealing and compaction. Hermawan and Bomke (1996) found that a grass ley crop consistently improved surface aggregate stability over a cash crop with winter cover. Similar improvements in soil structure of grassland over no-till or conventional cropland are abundant in the literature (Karlen et al., 1999; Elliot, 1986; Carter 1992; Dick, 1992). Improved soil structure or aggregation is indicated by an increase in WSA and higher proportions of macroaggregates, or higher MWD. Realistically, the only significant factors of soil structure that we can impact directly in Delta are the organic cementing agents. Thus, soil structure is improved by encouraging microbial activity.

"Biologically mediated processes in soils are central to the ecological function of soils." (Dick, 1992). Macroaggregates (>0.25mm) provide important habitat for soil microbes and microbial activity (ibid.) at the same time that microbes and their activity increase soil aggregation. In annual and perennial cropping systems, soil microbial biomass carbon has been correlated positively with both WSA and MWD (Drury et al., 1991). Chantigny et al. (1997) found close correlations between MWD and fungal glucosamine. The correlations were closest when aggregates from the >2mm fraction were studied. Thus, Chantigny (ibid.) concluded that fungi play a dominant role in soil aggregation. Vesicular arbuscular mycorrhzial (VAM) fungi help stabilize macroaggregation physically with their hyphae. VAM spore densities, fungal biomass and root colonization have been found to increase from conventional to minimum-till to pasture (Kahn, 1975, Schenck et al., 1982, Yocom et al., 1985). When Karlen et al. (1999) studied six paired (CRP vs. cropped) sites enrolled in the CRP in the United States, microbial biomass C was higher in all CRP sites. The difference was significant for four of the six sites. Haynes et al. (1991) found that just four years of pasture was adequate to stabilize aggregation and significantly increase soil microbial carbon. The mode of stabilization reported was increased amounts of binding carbohydrates in the rhizosphere due to higher microbial biomass. In addition to being larger, aggregates of grassland are more stable than aggregates of cultivated fields (Elliot 1986). Karlen et al. (1999) found that unstable aggregates had lower organic carbon content. Elliot (1986) also found a lower organic carbon content in cultivated soils. In the same study, cultivated soils had a larger proportion of microaggregates (0.053 to 0.30mm). Hermawan (1995) found that the organic carbon content of a Delta soil decreased with the number of years in cultivation after a grass crop. Dick (1992) concluded that the conversion of macroaggregates to microaggregates occurring with long-term cultivation is responsible for a reduction of biological activity.

In the soils of Delta, soil microbial biomass and activity will improve as a result of improved organic matter levels, structure and drainage, which will accompany the incorporation of grass back into the rotation.

2.3. Grassland Set-asides are Habitat for Wildlife

The habitat lost on Sea Island was important to many bird and small mammal species. Common bird species using both Sea Island and the set-asides include northern harriers (*Circus cyaneus*), red-tailed hawk (*Buteo jamaicensis*), rough-legged hawk (*Buteo lagopus*), great blue heron (*Ardea herodias*) and short-eared owls (*Asio otus*).

Habitat quality is "...the ability of the environment to provide conditions appropriate for individual and population persistence" (Hall et al., 1997). Habitat quality should be measured by population demography of the species of interest (Hall et al., ibid.). Since this is beyond the scope of this project, use of the set-asides by the species displaced from Sea Island will be discussed instead of population demography of the species.

Initially, the intention was to measure characteristics of the grassland set-asides that affect the habitat quality or use by species displaced by development on Sea Island. However, Summers (1998) reported that the most important feature of a set-aside determining bird numbers in a field was field size. He found that field location, number of voles, set-aside mix or other site characteristics (other than hedgerow, ditches and brambles) did not affect the bird density or numbers. Searing and Wiggins (1993) found the distribution and abundance of raptors on Sea Island to be closely correlated with the amount of available habitat. Studies on Sea Island by both Searing and Cooper (1992) and Searing and Wiggins (1993) found that use of fields by raptors varied with vole populations. Searing and Cooper (1992), list vole availability as a factor likely to limit populations of raptors. Voles are the primary food source for rough-legged hawks and when available, they are the primary food source for northern harriers (Searing and Cooper, 1992) also. They are the most important food source for red-tailed hawk, great blue heron and short-eared owls as well.

Searing and Cooper (1992) reported that old-growth fields provided the best habitat to voles. Summers (1998) found Townsend's vole (*Microtus townsendii*), and deer mice (*Peromyscus maniculatus*) among the small mammals using the set-asides. The structure of the plant canopy, cover, plant diversity and edible plant food quality are likely factors limiting vole populations. Searing and Cooper (1992) concluded that managing fields to provide sufficient cover and high plant growth rates would increase vole, and in turn, raptor populations. In support of this conclusion, Summers (1998) reported that Northern Harriers and Red-tailed Hawks were found to use set-asides 2 to 3 times more than would be expected due the amount of land in set-aside. Thus, the raptors mentioned above show a definite habitat preference for this tall grass habitat (Searing and Cooper, 1992, pers. comm. Marcus Merkens, DF&WT wildlife biologist,). Great blue herons used hayfields on Sea Island significantly more than expected given the area of hayfield available (Searing and Wiggins, 1993). In similar, earlier studies, Sullivan (1992) found that the northern harrier, the red-tailed hawk and the rough-legged hawk avoided cultivated fields and were significantly more attracted to old field habitats. Sullivan (ibid.) also found that the red-tailed hawk and the rough-legged hawk used overgrown pasture (the set-aside program was not established at that time) in a higher proportion than expected. Marcus Merkens has observed that the rough-legged hawk seems to prefer short grass habitat. Due to morning and night hunting habits, there were not enough sightings of short-eared owls to draw conclusions regarding their set-aside use (pers. comm. Marcus Merkens). Other birds using grassland set-asides include the savanna sparrow and the western meadowlark (pers. comm. Marcus Merkens).

2.4. The DF&WT Seed Mix.

The DF&WT has been developing its seed mix of perennial grasses and clover for the Grassland Set-aside program since 1996. The mix was designed with three main objectives in mind. Firstly, the components of the mix should contribute to soil conservation and remediation. Secondly, they should provide habitat in the form of food and or shelter and or hunting ground for small mammals and raptors. Finally, the grasses should be capable of producing good quality hay, should the grower decide to take a hay crop. For several reasons, most of the farmers do not take a hay crop and as a result, this last objective has become less important. Currently, the mix consists of orchard grass *(Dactylis glomerata*), tall fescue (*Festuca arundinacea*), short fescues *(Festuca rubra var. commutata* and *F. rubra var. rubra*), timothy (*Phleum pratense*), and red clover (*Trifolium pratense*) (See Table 5.3.2.A). The mix is sewn with or without a nurse crop. The farmer generally chooses a cereal (usually barley or oats) or annual ryegrass (*Lolium multiflorum*) as a nurse crop.

Both annual and perennial ryegrasses (*Lolium multiflorum* and *L. perenne* respectively) have good soil remediation capability and wildlife habitat value. Perennial ryegrass is a valuable herbage grass, establishing quickly and being nutritious (Hubbard, 1954). However, it requires a long drying period as hay and can at times be persistent after plough-down (pers. comm. Dr. Wayne Temple, UBC). As a result, perennial ryegrass was removed from the mix. Annual ryegrass, on the other hand, remains as an option for inclusion in the mix as a nurse crop. Like perennial ryegrass, it is favourable for small mammals and other wildlife as it provides both food and shelter. Annual ryegrass is sometimes used as a nurse crop because it establishes and creates cover much faster than other perennial grasses. The fact that ryegrass is a prolific seed producer, makes it valuable to wildlife (Summers, 1998), but also a potential weed in subsequent crops. In light of this, the annual ryegrass seed strain "Westerwolds" is a strict annual, meaning that it should not persist after plough-down. Its seeding rate has also been adjusted so as not to become competitive with other establishing grasses.

Tall fescue was added to the new '96 mix because it was found to have good soil remediation capability (Bomke et al., 1997). The rate was subsequently increased in 1997/98 after it was found to have good value to wildlife (Summers, 1998). It is also one of the few species that will tolerate poor soil conditions (see Table 6.2.2.B).

Both short fescues, creeping red fescue (*Festuca rubra subsp. rubra*) and Chewing's fescue (*Festuca rubra subsp. commutata*), were added because of their observed small mammal use (pers. comm. Dr. Wayne Temple, UBC). In addition, creeping red fescue is rhizomatous and therefore, promotes good sod formation and a full canopy.

Timothy is often found as a component of pastures in Delta because it performs well under wet and dry soil conditions. It is also observed to be of some habitat value to waterfowl and voles (pers. comm. Dr. Wayne Temple, UBC) and is the grass of choice for hay producers.

In humid areas, nitrogen is usually the limiting plant nutrient. Including a legume, a nitrogen fixer, to the grass mix increases the levels of nitrogen in the soil. The legume also increases the protein content of the hay crop. Initially, crimson clover (*Trifolium incarnatum*) was chosen for the mix. It was unsuccessful at establishing and therefore was replaced by red clover (*Trifolium pratense*) in 97/98.

In general, grasses will become more rapidly established under relatively cool and wet conditions. Therefore, in the spring, grassland set-asides should be planted as early as the ground and weather permits. This will ensure that good use is made of optimal growing conditions, including more available soil moisture and reduced weed competition. Early seeding will also promote a well-established grass stand in the fall that may provide some habitat value to small mammals or be less desirable to grazing waterfowl over the winter.

2.5. Plant Canopy Characteristics

Measuring plant canopy characteristics must be done in order to assess plant species abundance (cover and biomass) and plant species diversity (number of species per quadrat) relative to establishment methods and soil conditions. The abundance of vegetation is important to the quality of soil and habitat. Biomass becomes soil organic matter - the carbon source for microbes. Microbes, in turn, enhance soil structure and cycle nutrients back to plants. Vegetative cover protects the soil surface from the destructive forces of raindrops and wildlife. A fine balance of cover and bare ground will protect small mammals while providing good hunting ground for raptors. Diversity of plant species provides diverse food for wildlife and diversity in canopy structure for predators. Diversity also ensures at least some cover in areas of different soil conditions and when weather conditions at the time of germination may be unfavorable. Similar to soil quality testing, the evaluation of vegetation needs to be relatively easy and inexpensive to perform on an extensive scale.

2.5.1. Species Abundance

Species abundance can be assessed using several qualitative and quantitative methods. Quantitative measures of abundance include density, yield and frequency. Whereas, describing species abundance by measurements of cover may be either quantitative or qualitative.

Species density is the number of individuals of a species in an area (Goldsmith et al., 1976). Measures of species density require the ability to distinguish individuals. This can be a problem in clovers and grasses such as creeping red fescue, which spread and reproduce vegetatively (ibid.). Yield is a measure similar to density, however, it is based on biomass of a species rather than the number of individuals of a species. If distinguishing individuals is not a problem, species density is the preferred measure because it does not require biomass samples and it is an absolute measure. Yield, on the other hand, is relative to conditions affecting plant production. While yield is a common and representative means of describing vegetation, collecting, drying and weighing samples would not be a practical means of evaluating DF&WT set-asides.

Rooted species frequency is the chance of finding any one particular species rooted within a quadrat when the quadrat is placed (Kershaw, 1973). It is a useful measure where comparisons of species abundance are required on a large-scale. According to Kershaw, (ibid.) the error involved with estimating frequency is negligible relative to cover or density. However, the size of the quadrat, the size of the plant and the spatial distribution of individuals affect measures of frequency. Therefore, comparisons of frequency between different sample plots must use the same size quadrat, but whenever possible, more accurate methods should be used.

Cover refers to the proportion of ground covered by horizontal aerial plant parts of the species being considered (Greig-Smith, 1983). Once again, both qualitative and quantitative methods of measuring cover are available. The Point-frequency Frame technique is one qualitative method for measuring species cover. It is only applicable for vegetation between 20-50 cm tall. A frame is constructed of two legs and two cross bars. The crossbars have ten holes 10 cm apart. A pin is passed through the holes in the upper and lower cross bar and into the canopy. The number of 'hits' for each species is recorded and then divided by the total number of hits for all species. Cover for each species is expressed as a percentage. Although this measure of cover is considered good and is widely used for estimating plant abundance, it is limited. The method is tedious and slow, and therefore not practical for extensive surveys. In addition, this method is not used commonly anymore and the point-frequency frame itself is not suited to tall, upright vegetation.

The Braun-Blanquet Cover-abundance Scale (see table 2.5.1.A below) is a means of ranking rooted percent cover and abundance simultaneously. With this method, measures of cover are made by visual estimate and hence it is a qualitative method. Once the quadrat is placed, percent cover is estimated for each species. The abundance class adjusts for the fact that some species are short and wide, while others are tall and thin.

Table 2.5.1.A:The Braun-Blanquet cover-abundance scale

Combined from Goldsmith, Harrison & Morton (1976), p.450 and Mueller-Dombois & Ellenberg (1974), p.60

Symbol	**Class**	**% cover**	**Abundance class**
r		less than 1%	solitary
+	very rare	less than 1%	few
1	rare	1-5%	numerous or scattered
2	occasional	6-25%	any number
3	frequent	26-50%	any number
4	common	51-75%	any number
5	abundant	76-100%†	any number

†Due to overlapping layers of different species, total cover is often greater than 100%

Kershaw (1973) suggests that the accuracy of the Braun-Blanquet Cover-abundance scale is greater than other cover scales due to fact that the steps of the scale are uneven. This is said to compensate for the surveyor's bias to overestimate. Kershaw (ibid.) also suggests that the accuracy of this method can be improved by using subdivided quadrats. For example, using a $1m^2$ quadrat subdivided into 10 x 10 cm^2 grids, assign a Braun-Blanquet classification for every fourth grid. This modification would be useful for first year set-asides, but in subsequent years, the vegetation is too tall and wide for this to be practical. Although criticized for its lack of objectivity, this scale is widely used (Goldsmith et al., 1976) and there are few other practical means of estimating cover in tall stands or over large areas. Cover may be an adequate and convenient alternative to yield/biomass, however, the correlation between cover of standing crop and biomass will vary from species to species.

2.5.2. Species Diversity & Richness

"Species diversity at its simplest is a comparison of species richness" (Wratten & Fry, 1980). Species richness is the total number of species on a site. Measures of richness weight rare and common species equally. On the other hand, diversity indices usually account for the number, dominance or abundance of each species, and they do so more accurately than cover-abundance scales do. Diversity indices were designed this way because most natural communities consist of relatively many rare species and relatively few common species (Krebs, 1985). Where sites are seeded, weed populations fit this charactersitic, however, the majority of species are the seeded species which do not. In addition, like measures of density, diversity measurements require the ability to distinguish individuals, which may be a problem for some species. A simplified measure of diversity, such as the average number of species per quadrat, along with Braun-Blanquet Cover-abundance ratings might be a rudimentary, but suitable alternative to a diversity index for monitoring set-asides in Delta. Similar measures of diversity and richness were used by Poulton and Swash (1992) while monitoring and evaluating set-aside fields in England.

Chapter 3 SUMMARY

Due to its inherent characteristics, Delta ranks among the top 20% of land most suited for agriculture in the province of British Columbia (Leonoff et al., 1992). For this reason, the land in Delta's ALR should be considered highly valuable to farming and agriculture should remain its primary use.

There are issues related to soil and wildlife conservation on Delta farmlands. The solutions to these problems are within our technological means, but, for the most part, have been obstructed by social, political and economic situations.

The DF&WT has successfully created and implemented farm stewardship programs for the conservation of soil and wildlife in Delta. These programs have been implemented in a way that is feasible for farmers regardless of their land tenure. The Grassland Set-aside program is one of the more extensive of these programs involving approximately 260 ha (642 acres). This program provides compensation to farmers who, in turn, provide quality habitat to small mammals, passerines and raptors. During the grass period soil structure improves, making the soil more resilient to future farming activities. In order to achieve its soil and wildlife conservation goals, the DF&WT must be able to monitor and evaluate the progress of its Farmland Stewardship programs. There is a reasonable amount of literature available on assessing habitat value and soil improvements of grassland set-asides, however, it is largely restricted to set-asides in the Conservation Reserve Programs of Great Britain and the United States (outlined in section 1.2). The objectives and establishment protocols of these programs differ from those of the DF&WT. Therefore, the information and methods must be studied in the Delta area before they are relied upon as tools for evaluating the DF&WT's Grassland Set-aside program. This study will investigate a number of methods for assessing habitat and soil quality. Methods that are reasonably accurate, informative and efficient will be chosen to make up a protocol for assessing the Grassland Set-aside program on a large scale. This will be a valuable tool that will enable the DF&WT to monitor, evaluate and continually fine-tune characteristics of the Grassland Set-aside program keeping it sustainable into the future.

Chapter 4 OBJECTIVES

The general objective of this project is to contribute to long-term goals and activities of the YVR Stewardship Fund Monitoring Program (outlined in section 1.3). In meeting the three specific objectives of this project (described below), grassland set-asides were studied over up to three growing seasons using two approaches. At the small plot level, set-aside establishment practices were assessed. Plant species diversity, abundance and soil quality characteristics of the 1997/98 DF&WT Grassland Set-aside seed mix over different nurse crop and manuring regimes were assessed. At the multi-field level, set-asides seeded to the DF&WT Grassland Set-aside seed mix in 1996, '97, '98 and '99 and having different establishment regimes, but similar plant and soil characteristics as the small plots were studied. The objectives were as follows:

1) To assess plant species abundance, plant species diversity and soil quality of first, second and third year grassland set-asides seeded with the DF&WT seed mix.

2) To determine the effect of two different nurse crop species and a manure application on plant species abundance of the Delta Farmland and Wildlife Trust grassland set-aside seed mix and on soil quality in a small plot trial.

3) To investigate and design protocols that will enable the DF&WT to confidently assess the response of plant species abundance, plant species diversity and soil quality of grassland set-asides to different management practices.

Currently, the DF&WT Grassland Set-aside Program encompasses 260 ha (642 acres) of Delta's farmland. In establishing a protocol for monitoring and evaluating the success of the grassland set-aside program, reliable and efficient methods of sampling over a large scale must be identified. Both qualitative and quantitative methods for sampling plant species diversity and abundance exist. Unfortunately, quantitative methods are impractical for large scale monitoring, while qualitative methods tend to be subjective and therefore are considered inaccurate and imprecise. Comparisons and analysis of data gathered at the small plot and multi-field level may identify useful sampling methods and their associated confidence levels.

Chapter 5 MATERIALS AND METHODS

5.1. Sampling Methods

5.1.1. Plant Sampling Methods

The plant canopy was characterized using both quantitative (biomass) and qualitative (percent cover, present species lists) techniques. A $0.25m^2$ (0.5m x 0.5m) quadrat was randomly placed in the plot or field. First, all species present were identified and recorded. Next, percent cover was measured using a Braun-Blanquet Cover-abundance Scale (Table 2.5.A in Section 2, Literature Review). Finally, all plant biomass rooted within the quadrat was harvested. Biomass samples were dried at 60°C in a pot-hole dryer for at least 7 days and then weighed.

5.1.2. Soil Sampling Methods

A composite sample of the top 15 cm of soil was sampled for chemical, physical and biological characteristics. Chemical analysis included pH, EC, percent OM, total N, available P, and exchangeable K, Ca, Mg and Na. Soil physical characteristics were assessed by measures of aggregate stability (percent WSA and MWD). Soil biological activity was evaluated by means of earthworm counts.

5.1.3. Analytical Methods

Plant Canopy Characteristics: Lists of species present in each quadrat or field were used to calculate species richness (total number of species per site), species diversity (average number of species per quadrat) and species frequency (the chance of including a species in a quadrat). Yield/biomass, and percent cover-abundance data were also used.

Depending on the age of the grass stand, the scale of the study and the objectives at hand, vegetation characteristics were reported by species or category (ie. DF&WT grasses, seeded species, weeds, etc.). When percent cover-abundance data needed to be transformed from a species basis to a category basis, the Braun-Blanquet rank was worked back to the mid-point of the range and midpoints of species belonging to the same category were then added together. The final result was either left as percent cover or transformed back to a Braun-Blanquet rank.

Soil Chemical and Physical Lab Methods: Chemical soil quality indicators included pH, EC, percent OM, total N, available P, and exchangeable K, Ca and Mg and Na. In 1998, one composite sample was taken from each site (multi-field study) and each plot (small plot study) and sent to Pacific Soil Analysis Inc. (PSAI, Richmond, BC) for chemical analysis excluding pH and EC. In 1999, only samples for the new sites (multi-field study) and anomalous sites were analyzed. For new sites, one composite per field was sent to PSAI for OM, N, P, K, Ca, Mg and Na. Samples for pH and EC, were analyzed at UBC. For 1998, composite samples were used, whereas, for 1999, samples were kept on a per quadrat basis. Areas of fields showing relatively poor growth were divided into quadrants and 12 corresponding samples of plant characteristics and soil quality were collected. In each quadrant, samples were collected from areas having approximately 0%, 50% and 100% cover by seeded species. These data were used for a multiple linear regression analysis of cover with pH and EC. These samples were also processed at UBC.

All soil samples were air dried, then, either crushed with a rolling pin, or soil grinder and passed through a 2mm sieve. Soil pH, was measured at UBC on an ORION pH meter (model 420A). In 1998, pH_w was measured on the extract of a 1:2 soil:distilled water suspension, which was stirred several times over 30 minutes, then, allowed to settle for one hour before the reading was taken. In 1999, if fields showed high levels of EC, pH_W was measured first on a 1:2 soil:water suspension, then 0.05 ml of 3.6M $CaCl_2$ was added, the suspension was stirred several times over 30 minutes, then allowed to settle for one hour before the reading was taken. The pH_{CaCl2} overrides the effect of varying concentrations of soluble salts, giving a pH more likely to represent what plants experience under field conditions. According to personal communication with Bev Herman (PSAI), adding the $CaCl_2$ to the pH_w suspension should be as reliable as doing pH_{CaCl2} from the start.

EC was measured using a type CDM2e Radiometer Conductivity Meter. The supernatant was filtered off a separate suspension of 1 part water to 2 parts soil, for measuring EC ($EC_{1:2}$) EC is often measured on a saturated paste (EC_{sat}) from which an extract is suctioned. This method more closely represents field soil moisture conditions, however, using a 1:2 suspension is faster and more convenient in the lab since vacuum suction is not needed and the supernatant can be used for other measures (Kline & Kowalenko, 1993). Kline and Kowalenko report that the relationship between $EC_{1:2}$ and EC_{sat} is good at low salinity. Wolterson (1983) found a strong correlation between $EC_{1:2}$ and EC_{sat} on a soil very similar to those in this study over a wide range of salinity values (r=0.97 for EC_{sat} from 0.6 to 3.4). The linear regression equation was found to be Y=2.61X + 0.030 where $Y=EC_{sat}$ and $X=EC_{1:2}$. This equation has been used to estimate EC_{sat} from $EC_{1:2}$.

In 1998, exchangeable cations (K, C, Mg and Na) were analyzed at PSAI, whereas in 1999, they were done using comparable methods at UBC. In both cases, exchangeable cations were determined by the 1N Ammonium Acetate method at pH = 7.

For 1998 and '99 samples, OM, N and P were analyzed at PSAI. Since 58% of organic matter is carbon, OM was calculated by multiplying total carbon by a conversion factor of 1.72. Total C was determined using a LECO Carbon Analyzer. Total N was determined colorimetrically using a Technicon Auto-Analyzer on a semi-micro Kjeldahl digest. Available P was determined colorimetrically using the ascorbic acid method on a 1:10 soil:Bray P_1 extract (0.03N NH_4 in 0.025N HCl).

Physical and biological soil quality indicators included MWD, % WSA and earthworm counts. These indicators were limited to the 1998/99 small-plot study. Earthworm counts were carried out at the small plot site in May of 1998 only. One pit per plot was dug. Pits were approximately 20 cm x 20 cm x 20cm.

A variation of the wet sieving method (Yoder, 1936) was used to measure aggregate stability. A trowel was used to collect a cone shaped sample approximately 6cm in diameter and 7-10 cm deep. A sub-sample was taken by sieving out the 2-6 mm fraction from each sample. This fraction was refrigerated in sealed plastic containers for up to two weeks. To calculate gravimetric water content, 8-10g of the 2-6mm fraction were placed in aluminum drying tins and dried at 105°C for a minimum of 12 hours. For wet sieving, 10-15g samples were placed on a stack of 2.00, 1.00 and 0.25mm sieves, humidified until moist then washed at 30 RPM for 10 minutes (Hermawan, 1995). Water stable aggregates were then dried at 105°C for a minimum of 12 hours and weighed. Results were expressed as WSA and

MWD. Water stable aggregates were calculated by dividing the total dried aggregates by the dry weight of the sample before washing (USDA, 1999). MWD was calculated using Van Bavel's calculation as described in Kemper and Rosenau (1986) where MWD = $\sum x_i w_i$. The mean diameter of each size fraction is denoted by x_i. The proportion of the total sample weight occurring in the corresponding size fraction is denoted as w_i and i goes from 1 to n where n is the number of size fractions including that lost through the bottom of the smallest sieve (<0.25mm).

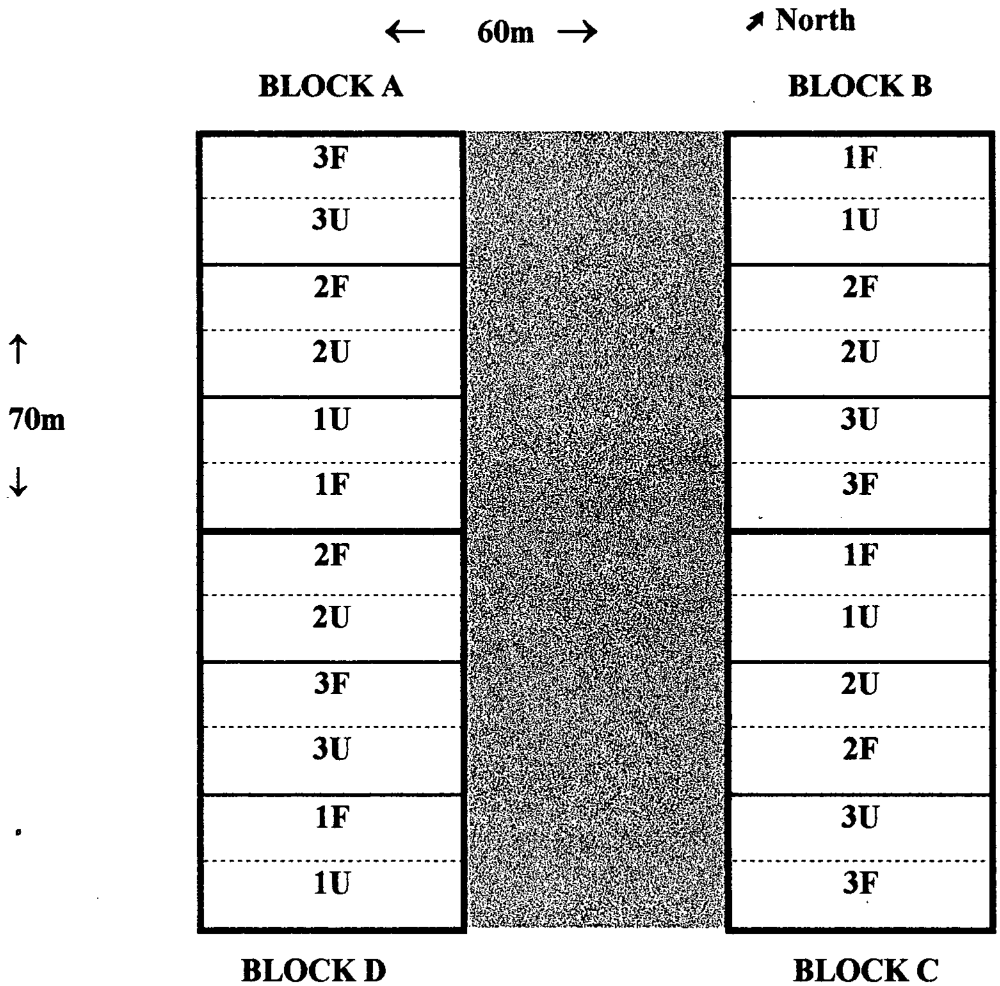
5.2. Set-aside Establishment (Small Plot) Study

In order to meet the first and second objectives noted above, a set-aside establishment, or small plot, study was done. This study compared the effect of two nurse crops, annual ryegrass (*Lolium multiflorum*) and spring barley (*Hordeum vulgare*), to the absence of a nurse crop, as well as the effect of a second year manure application, on plant species abundance, diversity and soil quality of plots seeded to the 1997/98 DF&WT set-aside seed mix in the spring of 1998.

5.2.1. Plot Design

The site was both disced and seeded at the Stan Reynolds Farm on Westham Island, in Delta, the second week of May, 1998. In the first sampling season, summer 1998, a randomized complete block design was used. Each block contained one plot of each of the three nurse crop treatments. In the second sampling season, summer 1999, plots were split and randomly assigned a fertility treatment. A total of four blocks was seeded allowing four replications of each fertility/nurse crop combination. The plot dimensions were 12m x 12m, making each block 36m x 24m. Including a 12m alley, the entire site was 60 x 72m.

Figure 5.2.1.A Small Plot Diagram, Stan Reynolds Farm,Westham Island, Delta BC.



1=no nurse crop
2=annual ryegrass nurse crop
3=barley nurse crop

F=fertilized
U=unfertilized

5.2.2. Seed Mix

The Delta Farmland and Wildlife Trust has been developing its seed mix of perennial grasses and clover for the Grassland Set-aside program. The 1997/98 seed mix is composed of five common species of grass and one clover species (Table 5.2.2.A).

Table 5.2.2.A: DF&WT Seed mix composition as applied to the small-plots.

Species	Percent of mix (by weight)
Orchard grass	25%
Tall Fescue	28%
Creeping Red Fescue	15%
Chewing's Fescue	15%
Timothy	15%
Red Clover	2%

5.2.3. Treatments

All seeds were sown May 13, 1998, at a 1-2 cm depth and a 10 cm row width using a 3 m width Vicon Air Seeder. In treatment 1 (Table 5.2.3.A), the DF& WT mix was seeded at 33 kg/ha alone. In treatment 2, one part annual ryegrass was added to three parts DF&WT seed mix. The resulting mix (treatment 2, Table 5.2.3.A) was seeded at 44 kg/ha. In treatment 3, a barley nurse crop was seeded at 78 kg/ha and the DF& WT mix was seeded at 33 kg/ha with a second pass of the seeder. Treatments 1 and 2 were mowed in order to control weeds during the summer of 1998. The cooperator applied a herbicide (MCPA) at the approprate rate to control weeds on the remainder of the set-aside.

Table 5.2.3.A Three methods of establishing the set-aside (small plot treatments)

TREATMENT	**1**	**2**	**3**
Rate of seed mix application	33 kg/ha	33 kg/ha	33 kg/ha
Annual Ryegrass nurse crop	-------	11kg/ha	-------
Barley nurse crop	-------	-------	78 kg/ha

† Mix #1 is seeded under a cereal nurse crop, while mix #2 has an annual ryegrass nurse crop.

5.2.4. Manure Applications

In order to determine if manure application has any affect on species diversity or species abundance, and soil quality, the nurse treatment plots were split and two manure applications were randomly assigned. Plots labeled 'F' received an application of 8.9 t/ha (4.0 T/acre) of poultry manure in the middle of May, 1999, while plots labeled 'U' received no application. The rate of manure application was found to supply 342 kg total N/ha (305 lbs total N /acre). Manure was applied in the second year because previous observations of the establishment of set-asides were that manure applied at the time of seeding the site resulted in increased weed competition (pers. comm. Dr. Art Bomke, UBC).

5.2.5. Sampling Methods

Soil Quality Assessment: The small plot area was sampled for soil chemical qualities (pH, EC, OM, total N and P, and exchangeable K, Ca, Mg and Na) in May of 1998 prior to seeding. In order to record soil chemical differences among blocks, one composite sample from each block was made up from 10 – 15cm cores collected with an Oakfield soil probe. Soil physical characteristics were evaluated by % WSA and MWD as described in section 5.1.3. For physical analyses, in May of 1998 one sample was collected per plot while in May of 1999 one sample was collected from each sub-plot.

Plant Population Characteristics: The plant canopy was characterized according to techniques described in section 5.1.1.3. A $0.25m^2$ quadrat was randomly placed two times within each plot or sub-plot. Percent cover was categorized as clover, DF&WT grasses, nurse crop or weeds. Plant biomass was also harvested and divided into one of the same five categories; clover, DF&WT grasses, nurse crop or weeds.

5.2.6. Statistical Analysis

All statistical analyses were done using analysis of variance (A.N.O.V.A.), correlation or regression on SAS for windows version 6.12. When differences between treatment means were significant, comparisons of the means were done using Bonferroni's multiple range test ($p<0.10$). Although for several tables p-values are given, the significance level chosen here is that commonly used in agricultural experiments ($p<0.10$). Further discussion on each individual analysis can be found in the relevant section of the results and discussions and A.N.O.V.A tables can be found in the appendix.

5.3. Multi-farm Set-aside Survey

5.3.1. Treatments

Plant canopy characteristics and soil quality measures were studied at the multi-field level over two fields seasons and on cohorts from the 1996, '97 '98 and '99 establishment years.

Table 5.3.1.A: Establishment and mowing regimes of the cohorts of the multi-field grassland set-aside survey.

Season(s)	Site	Seed mix	Nurse crop	Mowed – year I
		1996 Cohort		
1998	Montgomery	DF&WT old '96 mix	barley	grain & straw
1998	Savage	DF&WT old '96 mix	barley	grain & straw
1998	J. Harris	DF&WT old '96 mix	ann. ryegrass	mowed (weeds)
1998	R. Harris	DF&WT new '96 mix	ann. ryegrass	mowed (weeds)
1998	Chong/Guichon	DF&WT new '96 mix	ann. ryegrass	mowed (weeds)
		1997 Cohort		
1998	A. Singh (W.I)	DF&WT '97/98 mix	none	mowed (weeds)
1998 & '99	A. Singh (Ladner)	DF&WT '97/98 mix	none	mowed (weeds)
1998 & '99	P. Guichon	DF&WT '97/98 mix	barley	grain & straw
1998	Montgomery	DF&WT '97/98 mix	oats	grain / cut high
1998	R. Swenson	farmer's own	none	mowed (weeds)
1998 & '99	A. Berney	DF&WT '97/98 mix	barley	grain / cut high
		1998 Cohort		
1998 & '99	S. Reynolds	DF&WT '97/98 mix	barley	grain & straw
1998 & '99	D.Kamlah	DF&WT '97/98 mix	ann. ryegrass	herbicide
1998 & '99	R. McKimm	DF&WT '97/98 mix	none	mowed (weeds)
1998 & '99	D. Chong	DF&WT '97/98 mix	none	mowed (weeds)
1998 & '99	B. McKimm	DF&WT '97/98 mix	none	mowed (weeds)
		1999 Cohort		
1999	H. Reynolds	DF&WT '97/98 mix	barley	grain cut high
1999	K. Montgomery	DF&WT '97/98 mix	oats	grain & straw
1999	R & T. Harris	DF&WT 97/98 mix	barley	grain cut high
1999	D. Chong (W.I.)	DF&WT '97/98 mix	ann. ryegrass	mowed (weeds)
1999	G. Chahal	DF&WT '97/98 mix	oats	mowed (weeds)

5.3.2. Seed Mix

The DF&WT has been developing its seed mix of perennial grasses and clover for the Grassland Set-aside program. Table 5.3.2.A below shows the changes in composition of the seed mix since 1996. Mix #1 is usually seeded under a cereal nurse crop of barley or oats, while mix #2 has annual ryegrass as the nurse crop.

Table 5.3.2.A: Development of the DF&WT Seed mix composition and rate.

†Mix/ Species & rate	old'96 mix#1	old'96 mix#2	new'96 mix#1	new'96 mix#2	'97/'98 mix#1	'97/'98 mix#2
Seeding rate (kg/ha)	33%	44%	33%	44%	33%	44%
Perennial Ryegrass	32%	21%	22%	15%	-----	------
Annual Ryegrass	-----	33%	-----	33%	------	25%
Orchard grass	20%	14%	25%	17%	25%	18.75%
Tall Fescue	-----	-----	20%	13%	28%	21%
Creeping Red Fescue	25%	15%	-----	-----	15%	11.25%
Chewing's Fescue	20%	15%	30%	20%	15%	11.25%
Timothy	-----	-----	-----	------	15%	11.25%
Red Clover	-----	-----	-----	-----	2%	1.5%
Crimson Clover	3%	2%	3%	2%	------	------

† Mix #1 is seeded under a cereal nurse crop, while mix #2 has an annual ryegrass nurse crop.

5.3.3. Sampling Methods

A total of 21 sites from the 1996, '97, '98, and '99 cohorts was sampled for soil quality and or plant species population characteristics. At each site, 12 sample spots were systematically mapped out to represent the general field condition.

Plant Population Characteristics: For the multi-field study, percent cover was recorded by species for established sites and by category (clover, DF&WT grasses, nurse crop or weeds) for sites in their first year. Rooted biomass was divided into standing and litter biomass. For first year sites, sampling was done in fall to allow the stand to reach maximum biomass. For second and third year sites, sampling occurred over late July to mid-August in 1998 and August in when maximum biomass was reached.

Soil Quality Assessment: A composite sample of the top 15 cm of the soil was collected by taking several cores from each quadrat. In 1998 one composite was made for each field ('96, '97 & '98 cohorts), while in 1999 ('99 cohort), one composite for each quadrat was used. Soil chemical analysis included pH, EC, OM, total N and P, and exchangeable K, Ca, Mg and Na as described in section 5.1.3. In 1998, 7 of 21 fields had small areas showing markedly poor establishment or growth of the seeded species. These areas were sampled separately for soil chemical quality and the plant species present were identified and recorded in an attempt to determine the detrimental factor. Soil conditions were assessed based on a composite sample of the top 15cm of soil. In 1999, four of the anomalous areas were studied more closely. This time, areas of poor growth were divided into quadrants and 12 samples of cover and soil quality were collected. In each quadrant, corresponding plant and soil samples were collected from areas having less than 10%, approximately 50% and approximately 100% cover by seeded species.

5.3.4. Statistical Analysis

On anomalous areas, multiple linear regression analysis was run using both Braun-Blanquet Cover-abundance Ranks and actual percent covers to determine which soil quality factor (soil salinity or low pH), had a stronger negative effect on the establishment of the seeded species. A One-way Analysis of Variance was used to compare the variation within sites to the variation between sites within each cohort. This analysis was used to determine if site had a significant effect on plant canopy characteristics. Once again, all differences between treatment means were compared using Bonferroni's multiple range test, SAS for windows version 6.12 was used for all analyses.

Chapter 6 RESULTS AND DISCUSSION

6.1. Set-aside Establishment (Small Plot) Study

6.1.1. Local Weather Conditions During the Study Period

The Delta of the Fraser River is suited for production of a wide range of crops compared to most other areas of Canada. The Lower Fraser Valley has the longest frost-free period (>200 days) in British Columbia and the rest of Canada (Bertrand et al., 1991). Winters are cloudy and mild while summers are warm, but not hot. Seventy-eight percent of the annual precipitation occurs between October and April (Bertrand et al., 1991). The weather data below were recorded at Environment Canada's Weather station at the Vancouver International Airport. Data beyond May 1999 was unpublished at the time of writing this thesis.

Figure 6.1.1.A: Maximum monthly temperatures.

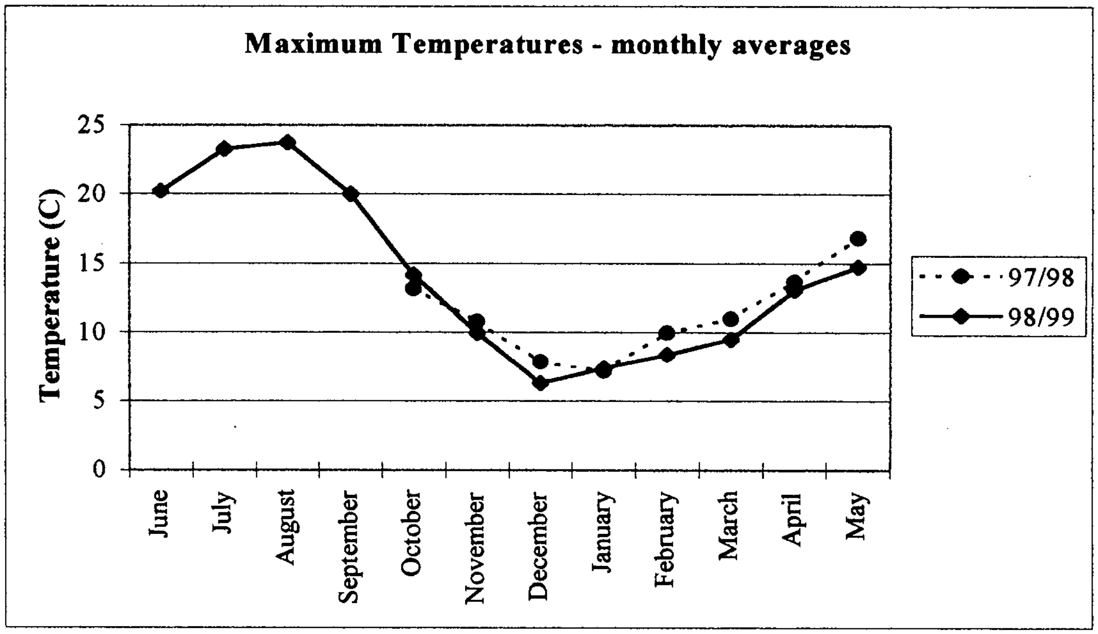


Figure 6.1.1.B: Minimum monthly temperatures.

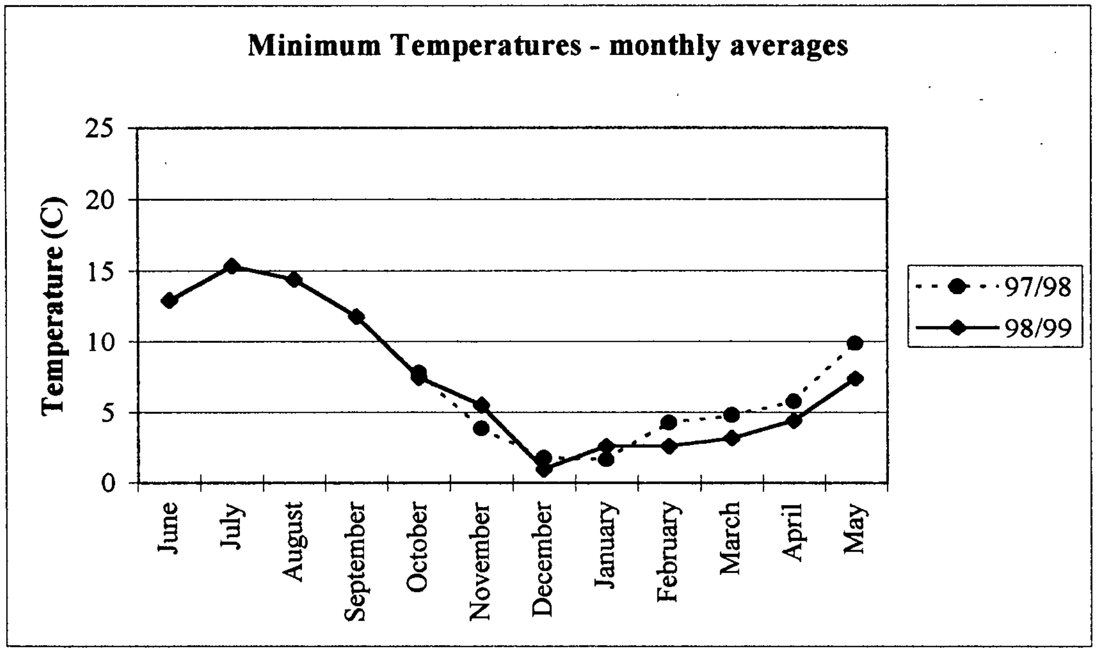
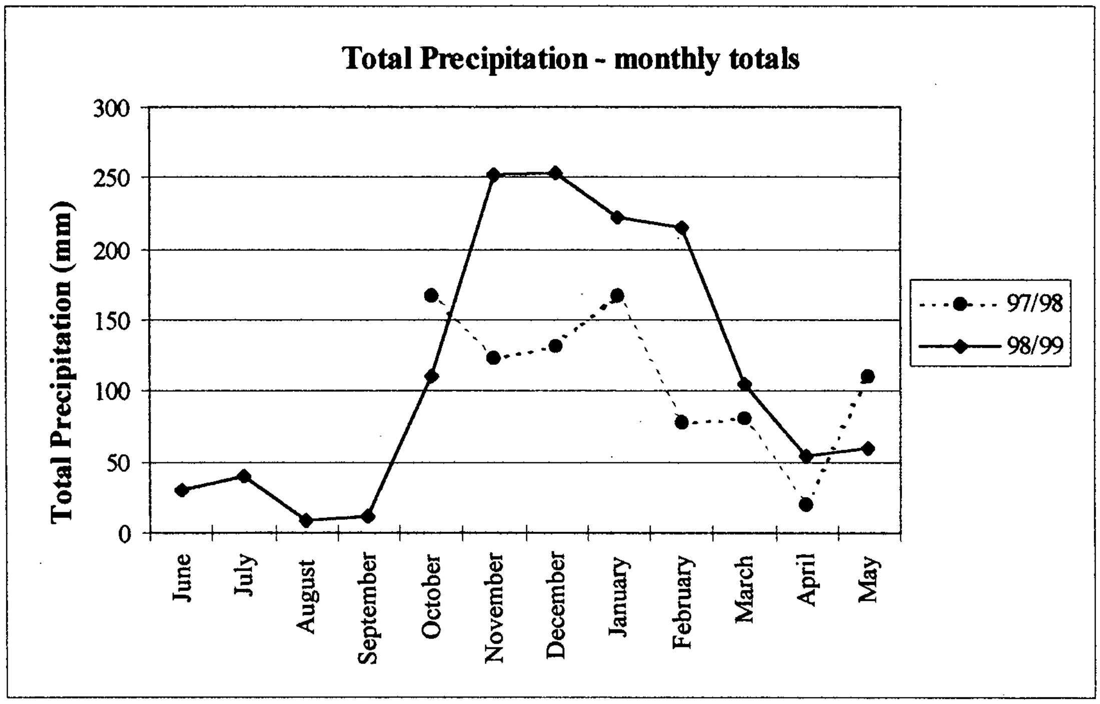


Figure 6.1.1.C: Total monthly precipitation.



6.1.2. Conditions at Field Work-up – Chemical and Physical Soil Qualities

The soils of the small plot site belong to the Crescent series, which is considered to be among the best agricultural soils in the Lower Mainland. Increasing organic matter levels and using artificial drainage should allow good production of almost all climatically suited crops (Luttmerding, 1981b).

The small plot area was sampled for soil chemical qualities (pH, EC, OM, total N and available P, and exchangeable K, Ca, Mg and Na) in May of 1998 prior to seeding. One composite sample was taken from each block. Soil chemical conditions at the small plot site were found to be favorable for the growth of the seeded species (Table 6.1.2.A). Neither pH, nor EC would have limited growth of the seeded species. Levels of organic matter are more likely to affect plant growth via soil structure. Since grasses have a relatively low calcium demand and the Crescent soils are fine textured and relatively young, calcium deficiency would be highly unlikely. The level of total nitrogen in the small plot area was found to be in the middle of the range commonly found in the top 1 ft of most cultivated soils in the United States (Tisdale et al., 1993). Due to high rainfall in the lower mainland, levels of plant useable nitrogen (NH_4^+ and NO_3^-) are minimal at springtime. Levels of available phosphorus and exchangeable potassium were beyond 'very high' on the scale recommended for the seeded species (Neufeld, 1980). Applications of magnesium are not recommended for soils containing levels higher than 99 ppm soil (0.82 meq/100g soil) (Neufeld, 1980).

Table 6.1.2.A: Soil chemical conditions at work-up.

Block	pH	EC_{sat} (dS/m)	Organic matter (%)	Total N (%)	Avail. P (ppm)	Exchangeable nutrients (meq/100g soil) K	Ca	Mg
A	5.6	1.13	2.9	0.15	205	0.83	7.50	1.38
B	5.4	1.08	2.8	0.15	215	0.68	6.50	1.18
C	5.3	1.13	2.5	0.14	133	0.73	7.00	1.68
D	5.7	0.92	2.1	0.14	200	0.63	8.25	1.50
Mean	5.5	1.06	2.6	0.15	188	0.72	7.31	1.43
S.D.	0.18	0.099	0.33	0.010	37.4	0.086	0.746	0.209
C.V.	3.27%	9.31%	12.7%	6.67%	19.9%	11.9%	10.2%	14.6%

S.D.= standard deviation of the mean
C.V.= coefficient of variation: the standard deviation expressed as a percentage of the mean.

Between discing and seeding, one sample per plot was collected for aggregate stability analysis. By this time, the field had been prepared for sowing. No significant difference in MWD or percent WSA was found between blocks (Table 6.1.2.B). Suitable levels of WSA would be between 70 and 75% for a soil such as this, having 2.6% organic matter and 21% clay (USDA, 1999) (% clay is estimated from Luttmerding, 1981c).

Table 6.1.2.B: Soil physical conditions at work-up.

Block	MWD	WSA (%)
A	3.1	70.3
B	3.2	69.9
C	3.0	69.8
D	3.0	70.2
Mean	3.1	70.1
S.D.	0.1	3.8
C.V.	3.22%	0.05%

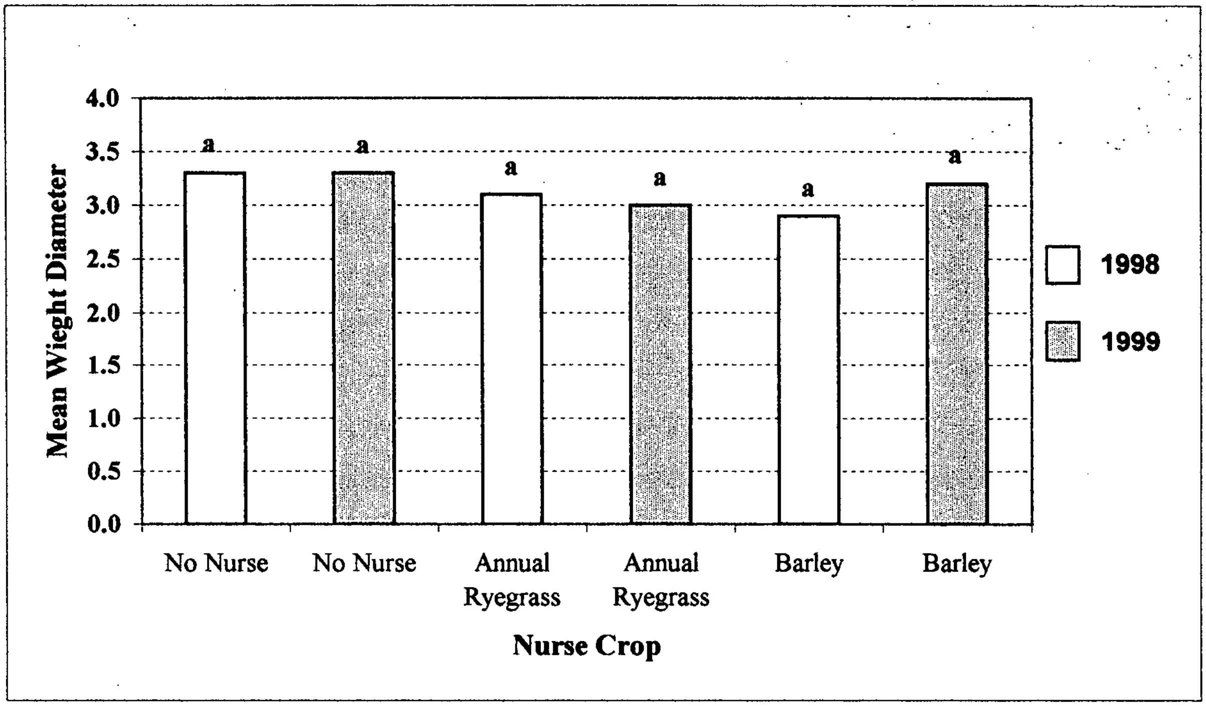
S.D.= standard deviation of the mean
C.V.= coefficient of variation: the standard deviation expressed as a percentage of the mean.
WSA = percentage of soil greater than 0.25mm

Initially, the biological indicator chosen for soil quality was earthworm counts. Earthworms were scarce at the small plot site in May of 1998. The very low level of earthworms found in the upper layer of soil was suspected to be due to the unusually dry spring. In this study, earthworm counts were found to be too variable to be a reliable soil quality indicator and therefore, were not repeated or reported. Other direct methods of measuring soil biological activity are costly and complex. Since WSA and MWD are correlated with biological activity (Drury et al., 1991 and Chantigny et al., 1997), they can be considered indirect biological soil quality indicators.

6.1.3. Effects of Nurse Crop Treatments on Soil Aggregate Stability

In May of 1999, after one year of set-aside growth, samples for aggregate stability analysis were taken. There was no block effect and no significant difference in MWD or WSA between nurse crop treatments (data not shown). Dapaah and Vyn (1998) found significantly higher wet aggregate stability in barley plots with an annual ryegrass cover crop when compared to barley alone. In that experiment, the annual ryegrass cover was maintained for one year after which time a herbicide was applied and the field was prepared for corn planting. They measured wet aggregate stability two to four months after establishment of the corn crop.

Figure 6.1.3.A: MWD Over Two Years and Three Nurse Crop Treatments.



bars with same letter are not significantly different using Bonferroni's Multiple Range test, alpha = 0.1

WSA increased significantly from 70.0% in 1998 to 73.6% in 1999. This is consistent with studies by Karlen et al. (1999) where WSA on Conservation Reserve Program (CRP) sites paired with cropland sites that were cultivated in a similar manner to the small plot site were found to be significantly higher. These sites were seeded to a grass-legume mix, however there is no indication how long the sites were in the CRP before the measures were taken.

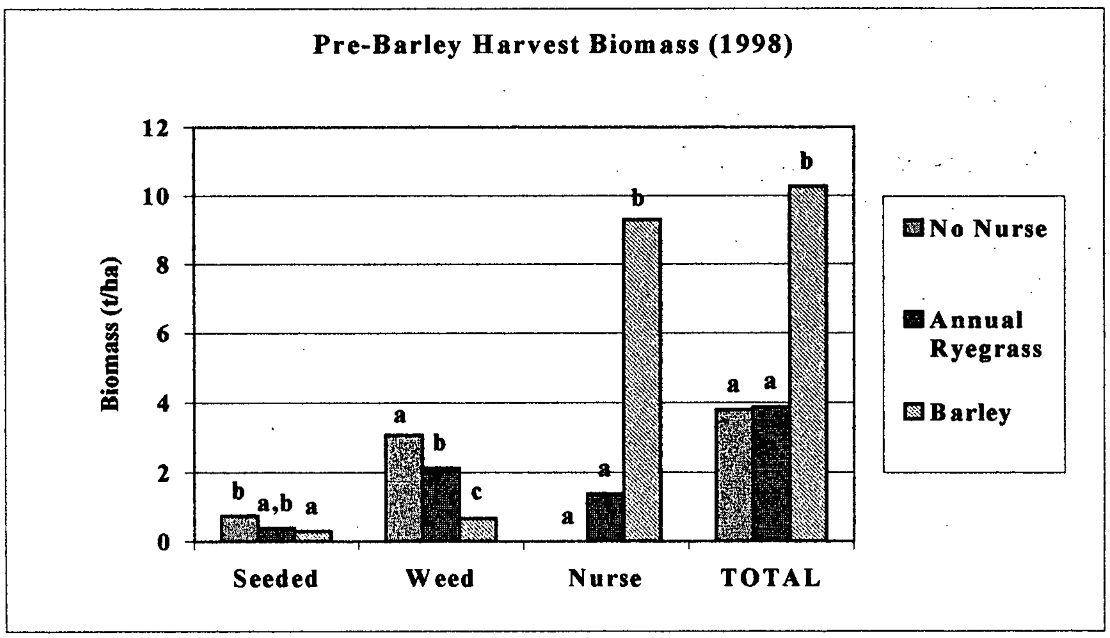
When MWD data from 1998 and 1999 was compared, no significant difference was found to occur after the establishment of the stand (see Figure 6.1.3.A). Variable factors affecting MWD include freezing and thawing (Perfect et al., 1990), tillage, weather and biological activity (Lehrsch and Jolley, 1992), soil water content, current crop and cropping history (Dapaah and Vyn, 1998), fungal populations (Chantigny et al., 1997), microbial biomass, and biological activity. Excluding weather and soil water content, all factors were expected to change in a way that would increase MWD with the establishment of the set-aside mix. Soil water content was unlikely to oppose the positive effects of the grass mix as gravimetric water content was identical at both sampling dates and over all samples except one (data not shown). Further, the effect of soil water content at time of sampling on structural stability is less pronounced on soils of relatively low clay content (Carter et al., 1994) as are the Crescent soils. Key factors responsible for the lack of change in MWD over the first and second year include the facts that the soil at the site was in good condition and the rainfall between the first and second year of the study was quite variable. It is suspected that because the initial MWD was relatively good at the small plot site (see section 6.1.2), significant increases in MWD are less likely to occur. This is similar to the small variation in aggregate stability seen by Davies and Younger (1994) after the establishment of a grass ley crop on a relatively well-structured clay loam. Hermawan (1995) found that aggregate stability improved significantly under a grass ley crop of tall fescues and timothy over a two-year period. However, soils of that study were so severely degraded that the MWD's were less than 2 mm. The winter of 97/98 had less total precipitation (876.5mm) than that of 98/99 (1271.5mm). Less precipitation in the winter of 97/98 meant less structural damage due to standing water on the field. In a study in Texas, U.S.A., Unger (1991) found that cold, dry winters increased soil stability. Although our winters are more mild and wet in general, the winter of 97/98 was cooler and dryer than the winter of 98/99. Between October 1997 and May 1998, there were 27 days where temperatures dipped below 0 °C compared to 20 in the winter of 1998/99. There were no block effects and no interactions between nurse crop treatment and year for any analyses on MWD or WSA.

6.1.4. Effect of Nurse Crop Treatment on Abundance of Seeded and Weed Species in the First and Second seasons

A nurse crop is a fast growing species that is seeded with the main crop for several purposes. Firstly, it will suppress weeds while the slower growing main crop establishes. It will also protect the smaller, main crop from desiccation and wind damage. Finally, it will provide valuable cover for the soil and wildlife in the first year of a grassland set-aside. Figures 6.1.4.A and 6.1.4.B below show the biomass of seeded species, weeds and nurse crops before barley harvest (August) and after barley harvest (November 1998) respectively. Figure 6.1.4.A shows that plots with nurse crops (treatments 2 & 3) did have lower weed biomass than plots with no nurse crop (treatment 1) in August, 1998. This figure also shows that barley was more effective than annual ryegrass in terms of weed suppression. Seeded species had the lowest biomass under barley and the highest biomass without a nurse crop with the only significant difference being between no nurse and barley. Comparing biomass of seeded species between Figure 6.1.4.A and Figure 6.1.4.B it is seen that the effect of barley suppressing the seeded species disappeared after the barley was harvested. As predicted, seeded species had initially lower biomass than the weeds regardless of nurse crop treatment (Figure 6.1.4.A). Creamer et al. (1997) found that tall fescue, perennial ryegrass and orchard grass did not compete well with taller, more vigorous species such as rye and barley in several legume-grass cover crop mixes.

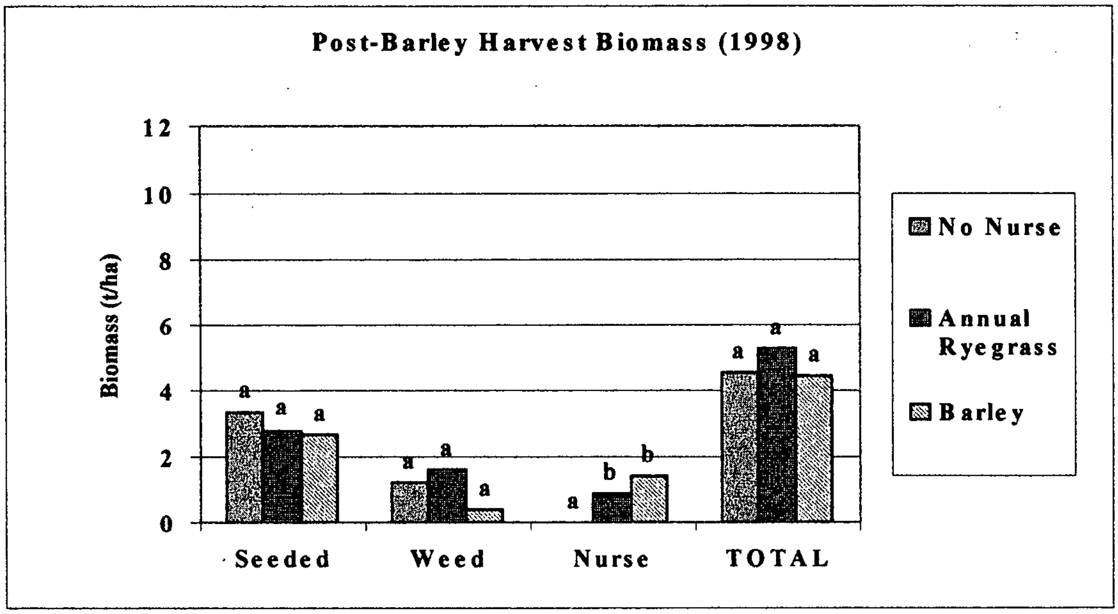
Between late summer and late fall, the seeded species gained biomass while weed species did not (Figure 6.1.4.B). This is most likely a result of annual weed species dying off and seeded species having a flush of growth with cooler weather and increased precipitation. By late fall (Figure 6.1.4.B) the effect of the nurse crop treatment on biomass of seeded and weed species and weed total biomass had disappeared. There was no effect of nurse crop on the biomass of seeded and weed species in the second season of the set-aside (Figure 6.1.4.C).

Figure 6.1.4.A: Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Establishment Year, August 1998).



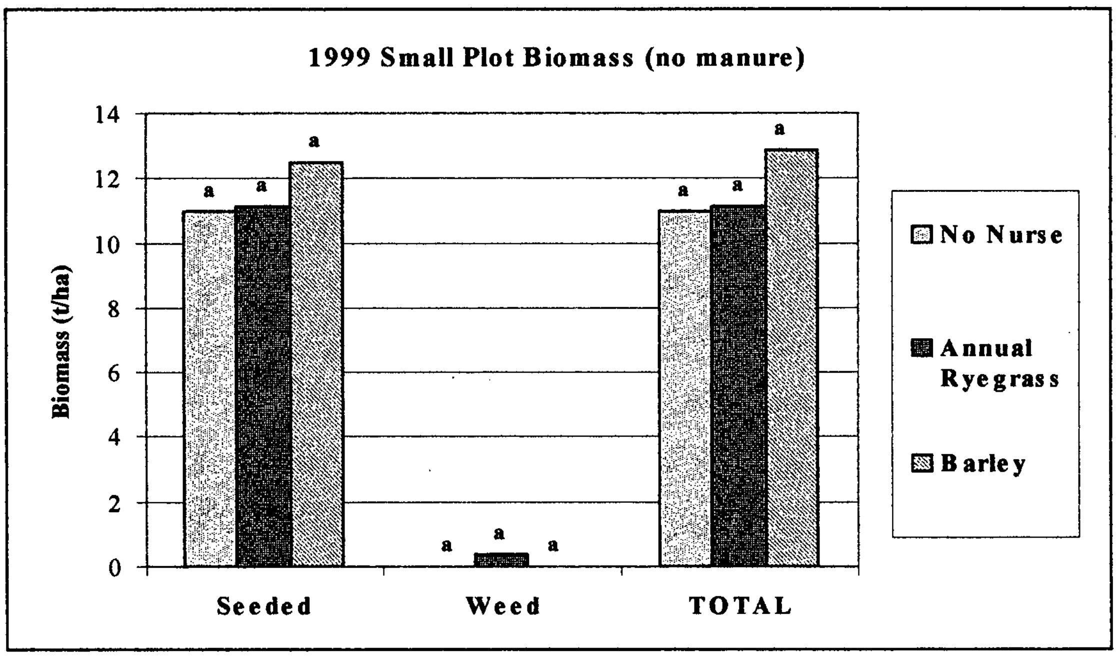
bars with different letters are significantly different at p=0.1 using Bonferroni's multiple range test.

Figure 6.1.4.B: Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Establishment Year, November 1998).



bars with different letters are significantly different at p=0.1 using Bonferroni's multiple range test.

Figure 6.1.4.C: Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Second Season, August 1999).



bars with different letters are significantly different at p=0.1 using Bonferroni's multiple range test.

6.1.5. Effects of Manure Application on Abundance of Seeded and Weed Species in the Second Season.

As discussed in Section 5.2.4 previously, poultry manure was applied as a fertility treatment to supply 342 kg total N/ha (305 lbs total N/acre) to the small plots in spring of 1999. It is estimated that approximately 50% of the total nitrogen applied would be readily available to plants (pers. comm. Dr. Art Bomke, UBC). The effect of the manure treatment on seeded species and weed biomass over the different nurse crop treatments was monitored. Table 6.1.5.A below shows that there was neither blocking effect nor interaction between nurse and fertility treatment by August 1999. No significant effect of nurse crop or manure application on either total, seeded species or weed species biomass was found ($p<0.10$).

Table 6.1.5.A: A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Biomass (t/ha) of Seeded and Weed Species (Sampled August 1999).

Species	Manure	Nurse Crop				A.N.O.V.A. p-values			
	(+/-)	None	Ann. Rye	Barley	ave.	Nurse	Manure	Blocks	M x N
Seeded	+	11.0	11.1	12.5	11.5	0.9013	0.1065	0.1488	0.1472
	-	11.3	10.3	9.8	10.5				
	ave.	11.2	10.7	11.1					
Weed	+	0.0	0.0	0.4	0.1	0.3623	0.3002	0.4363	0.3429
	-	0.0	0.0	0.0	0.0				
	ave.	0.0	0.0	0.2					
Total	+	11.0	11.1	9.26	11.7	0.8657	0.0876	0.1408	0.1152
	-	11.3	10.3	9.8	10.5				
	ave.	11.2	10.7	11.3					

In an experiment with red clover and annual ryegrass seeded under barley and winter wheat crops, Dapaah and Vyn (1998) found no significant difference in dry matter yield ($p<0.05$) four to seven months after applications of 0.5, 1.0 and 2.0 times the nitrogen recommended. However, since the grain crop also did not respond to the nitrogen application, it was suspected that nitrogen levels were adequate at or before the low application.

Table 6.1.5.B shows that total percent cover was not significantly different among the fertility treatments. However, the cover by orchard grass was significantly higher with the fertility treatment while cover by short fescue was significantly lower with manure application ($p<0.10$). Parish et al. (1989) found that fertilizer application to a grass and clover sward resulted in an increased abundance of orchard grass and a decreased abundance of clover.

Table 6.1.5.B: A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Cover of Individual Seeded and Weed Species (Sampled August 1999).

Species	Manure	Nurse Crop				A.N.O.V.A. p-values			
	(+/-)	None	Ann. Rye	Barley	ave.	Nurse	Manure	Blocks	M x N
Seeded Species									
OG[1]	+	2.9	2.5	2.5	2.6	0.6051	0.0493	0.0867	0.8348
	-	2.2	2.1	1.7	2.0				
	ave.	2.6	2.3	2.1					
TF[1]	+	4.2	3.1	3.5	3.6	0.2377	0.1464	0.3918	0.8563
	-	4.7	4.1	4.0	4.3				
	ave.	4.5	3.6	3.7					
SF[1,2]	+	0.25	0.0	1.5	0.6	0.1250	0.0438	0.6447	0.1470
	-	1.1	1.9	1.4	1.4				
	ave.	0.7	0.9	1.4					
Ti[1]	+	0.2	0.0	0.1	0.1	0.2746	0.5879	0.2392	0.9247
	-	0.3	0.1	0.2	0.2				
	ave.	0.25	0.06	0.2					
RCl[1]	+	3.9	4.5	3.7	4.0	0.8492	0.6501	0.2830	0.5335
	-	4.1	4.1	4.4	4.2				
	ave.	4.0	4.3	4.1					
Weed[1]	+	0.0	0.0	1.2	0.4	0.2205	0.5879	0.2861	0.0613
	-	0.0	0.7	0.0	0.2				
	ave.	0.0	0.4	0.6					
Total[1,3]	+	6.0	5.7	6.0	5.9	0.1250	1.000	0.6915	1.000
	-	6.0	5.7	6.0	5.9				
	ave.	6.0	5.7						

OG=orchard grass, TF=tall fescue, SF=short fescues, Ti=timothy, TCl=red clover, weed=anything other than seeded species.
1 Braun Blanquet Cover-abundance Scale.
2 short fescues = Chewing's and creeping red fescues.
3 Nurse by Block interaction for total percent cover not shown in this table, p = 0.0216.

When the effects of nurse and fertility treatments were observed for cover data on individual species there was an interaction between manure and nurse for the cover of weed species. This is due to the small number of plots in which weeds occurred. Of 48 samples, 44 had 0% weed cover and four had some weed cover. As a result, weed cover data should not be interpreted. Both experimental and sampling errors were significant for tall fescue and red clover at alpha of 0.10 (errors not shown here). This means that the error of tall fescue and red clover cover data was high; probably due to the subjective nature of the method of estimating cover.

6.1.6. The Relationship Between Visual Estimates of Cover and Biomass

As discussed in Section 5.2.5, plant canopy characteristics were measured by harvesting rooted biomass as well as estimating percent cover by category (DF&WT grasses, weed, clover or nurse). Estimations of percent cover are more efficient means of evaluating large areas of set-asides, however, they are considered less accurate. This study included a correlation analysis (see Table 6.1.6.A) between biomass and cover across nurse crop and fertility treatments in both the first and second year of the small plot study. All correlations between biomass and cover data were positive and significant ($p<0.10$). Table 6.1.6.B shows that although correlations were all positive and significant, measuring biomass will give bigger (significant) differences (see biomass vs. cover for seeded species). However, trends between biomass and cover are the same.

Table 6.1.6.A: Coefficients of Determination and Correlation Coefficients for Correlation Between Measured Biomass and Estimated Cover.

SPECIES	r2 values	r values
DF&WT grasses	0.469	0.685[1]
Clover	0.087	0.295[1]
Weed	0.755	0.869[1]
Nurse	0.669	0.818[1]

1 significant at p<0.10

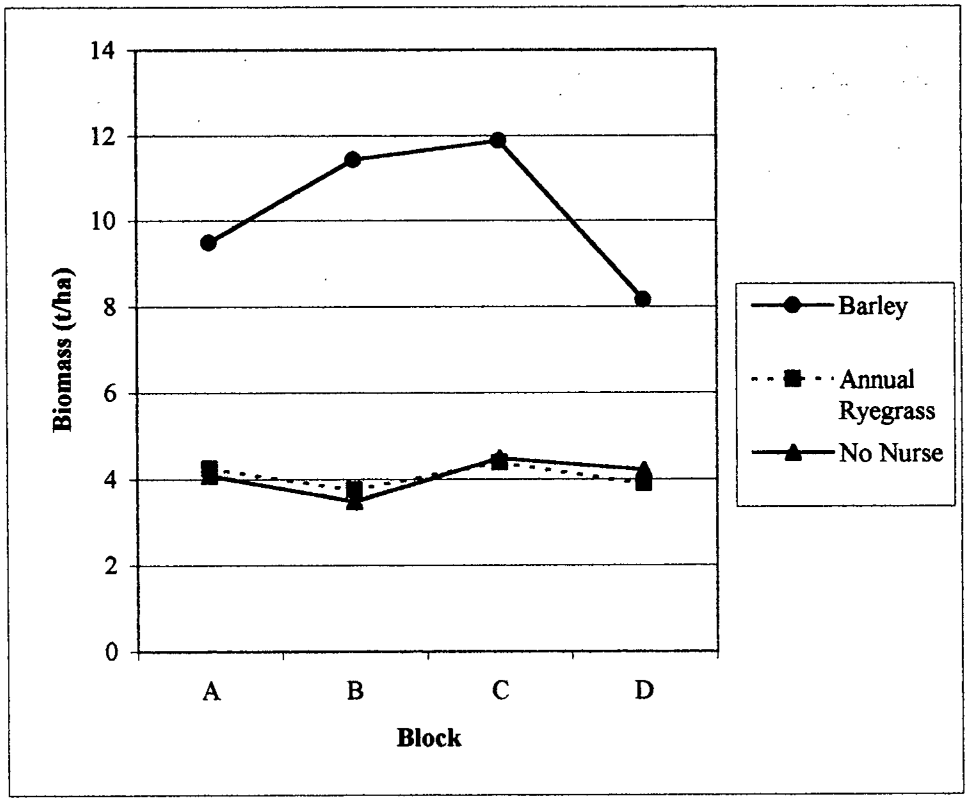
Table 6.1.6.B: Summary of Small Plot Results; Effect of Nurse Crop and Fertility Treatments on Biomass[1] and Percent Cover[3] (1998 data pre-barley harvest).

Species	Nurse Crop			A.N.O.V.A. p-values		
	None	Ann.Rye	Barley	Nurse	Blocks	B x N
Seeded Species[2]						
biomass[1]	0.86[a]	0.63[a,b]	0.27[b]	0.0296	0.8546	0.5389
cover[3]	3.7[a]	3.2[a]	2.9[a]	0.1553	0.1995	0.5605
Weed Species						
biomass[1]	3.2[a]	2.08[b]	0.748[c]	0.0001	0.2460	0.6385
cover[3]	5.0[a]	4.4[a]	2.1[b]	0.0010	0.1329	0.2209
Total Biomass						
biomass[1]	4.06[b]	4.07[b]	10.24[a]	0.0002	0.4143	0.0111
cover[3]	3.7[b]	4.2[b]	6.0[a]	0.0002	0.1565	0.6785

1 Biomass is in t/ha
2 DF&WT grasses plus clover, nurse crop is not included in this data.
3 Braun Blanquet Cover-Abundance ranks.
a, b, c: means with different letters are significantly different; Bonferroni's multiple range test; alpha=0.10.

The interaction between blocks and nurse for total biomass means that the response of total biomass to nurse crop varied among blocks. In this case, results for total biomass should be interpreted graphically, not by looking at p-values (see Figure 6.1.6.A below). When total biomass consists of all species except the barley nurse, the p-value for the nurse-block interaction is not significant (p = 0.6837). This indicates that the interaction is due to the inclusion of barley biomass in the total biomass. It is suspected that the interaction of barley biomass with block is due to a field margin effect as blocks A and D, which are closest to the field margin, have lower barley biomass.

Figure 6.1.6.A The Interaction Between Nurse Crop Treatment and Block for Total biomass (pre-barley harvest, 1998 data)



A comparison of the 1999 biomass and cover data lead to different conclusions in two instances (Table 6.1.6.C). Firstly, total biomass data show a significant difference due to fertility treatment, while total cover data does not ($p<0.01$). Secondly, there is an interaction between nurse and fertility treatments for cover data due to a small proportion of samples having weed cover, while biomass data does not show this interaction.

Table 6.1.6.C: Summary of Small Plot Results; Effect of Nurse Crop and Fertility Treatments on Biomass[1] and Percent Cover[2] (1999 data).

Species	Manure (+/-)	Nurse Crop None	Ann.Rye	Barley	ave.	A.N.O.V.A. p-values Nurse	Manure	Blocks	M x N
Seeded Species									
biomass[1]	-	11.0	11.1	12.5	11.5	0.9013	0.1065	0.1488	0.1472
	+	11.3	10.3	9.8	10.5				
	ave.	11.2	10.7	11.1					
cover[2]	-	6.0	5.7	6.0	5.9	0.1250	1.000	0.6915	1.000
	+	6.0	5.7	6.0	5.9				
	ave.	6.0	5.7	6.0					
Weed Species									
biomass[1]	-	0.0	0.0	0.4	0.1	0.3623	0.3002	0.4363	0.3429
	+	0.0	0.0	0.0	0.0				
	ave.	0.0	0.0	0.2					
cover[2]	-	0.0	0.0	1.2	0.4	0.2205	0.5879	0.2861	0.0613
	+	0.0	0.7	0.0	0.2				
	ave.	0.0	0.4	0.6					
Total Biomass									
biomass[1]	-	11.0	11.1	9.26	11.7	0.8657	0.0876	0.1408	0.1152
	+	11.3	10.3	9.8	10.5				
	ave.	11.2	10.7	11.3					
cover[2]	-	6.0	5.7	6.0	5.9	0.1250	1.000	0.6915	1.000
	+	6.0	5.7	6.0	5.9				
	ave.	6.0	5.7						

1 Biomass is in t/ha
2 Braun Blanquet Cover-Abundance ranks

6.1.7. Conclusions From Small Plot Study

There was no effect of nurse crop treatment or set-aside establishment on the MWD of soil aggregates. However, the percentage of WSA did increase significantly with the establishment of the set-aside. Using no nurse, a barley nurse or an annual ryegrass nurse crop did not affect biomass or cover of the seeded species past the fall of the first season. In this respect, the farmer may choose no nurse, annual ryegrass or barley depending on his/her cropping practices, or. However, the barley nurse crop does add significantly more total biomass and cover in beginning of the first year which may be valuable in terms of creating wildlife habitat (Table 6.1.6.B). Application of manure increased total biomass. When broken down into cover of individual species, the manure application increased cover by orchard grass and decreased cover by short fescue (Table 6.1.5.B). There is a significant positive correlation between biomass and cover (Table 6.1.6.A). Although trends of the two measures are the same, they resulted in different significant effects (Table 6.1.6.B and Table 6.1.6.C).

6.2. Multi-farm Set-aside Survey

6.2.1. Background

Monitoring was done on a sample of 21 fields taken from the total enrolled in the Set-aside Program. For each survey year, Table 6.2.1.A lists the sites of each cohort (all grassland set-aside sites in an establishment year) and their corresponding seed mixes. In the 1998 survey a total of 17 Set-asides, from the 1996, '97 and '98 cohorts, was sampled for soil quality and or vegetation characteristics. In the 1999 survey, a total of 14 Set-asides from the 1997, '98 and '99 cohorts were sampled for soil quality and plant species population dynamics. At each site, twelve sample spots were systematically mapped out to represent the field in general. For newly established sites, growth is very slow due to dry summer months and vigorous weed growth. Maximum biomass of seeded species for these sites is not reached until late fall brings cooler temperatures and more rain. For this reason, data for sites in their first season were collected in late fall of 1998 and fall 1999 while data for established sites were collected in late summer.

The Delta Farmland and Wildlife Trust has been developing its seed mix of perennial grasses and clovers for the Grassland Set-aside program. Table 5.3.2.A shows the changes in composition of the seed mix. Mix #1 is usually seeded under a cereal nurse crop, while mix #2 has annual ryegrass as the nurse crop.

Table 6.2.1.A: Sites Included in the Multi-field Study.

SITES (by establishment year)	SAMPLING YEAR(S)	SEED MIX
	1996 Cohort	
Montgomery 96	1998	DF&WT old '96 mix
Savage 96	1998	DF&WT old '96 mix
J. Harris 96	1998	DF&WT old '96 mix
R. Harris 96	1998	DF&WT new '96 mix
D. Chong/M.Guichon 96	1998	DF&WT new '96 mix
	1997 Cohort	
A. Singh 97 (Westham Isl.)	1998	✣DF&WT '97/98 mix
A. Singh 97 (Ladner)	1998 / 99	✣DF&WT '97/98 mix
P. Guichon 97	1998 / 99	DF&WT '97/98 mix
Montgomery 97	1998	DF&WT '97/98 mix
R. Swenson 97	1998	farmer's own
A. Berney 97	1998 / 99	DF&WT '97/98 mix
	1998 Cohort	
S. Reynolds 98	1998 / 99	✣DF&WT '97/98 mix
D.Kamlah 98	1998 / 99	DF&WT '97/98 mix
R. McKimm 98	1998 / 99	DF&WT '97/98 mix
D. Chong 98	1998 / 99	✣DF&WT '97/98 mix
Chahal 98	1998 / 99	DF&WT '97/98 mix
B. McKimm 98	1998 / 99	DF&WT '97/98 mix
	1999 Cohort	
H. Reynolds 99	1999	DF&WT '97/98 mix
Montgomery 99	1999	DF&WT '97/98 mix
R & T. Harris 99	1999	DF&WT '97/98 mix
D. Chong 99 (Westham Isl.)	1999	DF&WT '97/98 mix

✣ Richardson Seeds = Supplier rather than Dawson Seeds

6.2.2. Soil Chemical Conditions

Soil quality was represented by pH, EC, available P, and exchangeable K, Ca, Mg and Na (see Table 6.2.2.A). One composite sample was taken from each field in the 1998 survey, while in the 1999 survey, the new fields had one soil sample per quadrat.

Table 6.2.2.A Soil Chemical Status of Sites in the Multi-field Study.

SITE	pH (1:2)	EC_{sat} (dS/m)	Avail. P (ppm)	Exchangeable nutrients (meq/100g soil) K	Ca	Mg	Na
D.Montgomery 96	6.40	0.21	136	0.74	9.25	1.50	0.08
J.Harris 96	5.90	0.99	185	0.80	11.50	3.51	
R.Harris 96	6.01	0.39	138	0.54	13.80	3.51	0.58
Savage 96	5.26	0.37	62	0.70	7.80	2.79	0.14
Chong/Guichon 96	5.87	0.42	103	0.60	7.50	2.78	0.40
D.Montgomery 97	5.72	0.29	241	0.90	10.50	2.68	0.14
Singh 97 (Lad.)	5.74	0.52	200	0.88	12.30	1.53	0.25
Singh 97 (W.I.)	6.18	0.21	103	0.50	10.30	1.90	0.10
Guichon 97	5.88	1.07	67	0.60	10.80	3.75	0.21
Swenson 97	5.37	0.63	108	0.55	6.80	3.05	0.30
Berney 97	5.18	1.54	67	0.75	7.50	4.00	0.90
Kamlah 98	6.08	1.17	190	0.80	9.30	3.51	1.28
B.McKimm 98	5.73	1.59	262	0.90	9.80	3.75	0.90
R.McKimm 98	4.47	3.00	205	0.63	7.30	3.33	1.78
Chahal 98	5.14	1.31	144	1.32	10.50	2.38	0.75
[1]Chong 98	4.9	0.86	-	-	-	-	-
[1]S.Reynolds 98	5.5	0.34	-	-	-	-	-
H.Reynolds 99	5.75	1.20	93	0.60	4.50	1.29	0.90
K.Montgomery 99	5.58	0.44	218	0.98	4.75	1.16	0.15
R.& T.Harris 99	5.02	5.35	82	0.63	5.40	2.20	4.50
Chong (WI) 99	5.01	1.20	152	0.98	2.75	1.16	0.22
Mean	5.55	1.10	145	0.76	8.54	2.62	1.44
S.D.	0.48	1.17	62.05	0.198	2.814	0.941	2.07
C.V. (%)	8.7	106.8	42.7	26.069	32.94	35.90	143.20

[1] **some soil data not available due to late sampling.**
S.D.= standard deviation:
C.V.= coefficient of variation: the standard deviation expressed as a percentage of the mean.

The following broad generalizations can be made on plant tolerance to pH; red clovers and orchard grass are suited to pHs ranging from approximately 5 to 8.5, timothy and tall fescue are suited to between 5 and 7 and red fescue is suited to about 4.5 to 6.5. (Brady, 1990 and Neufeld, 1980). From this information, the seeded species seem to be able to tolerate a wide range of pH relative to what is seen on the set-asides. The only field with a pH that might have hindered establishment and growth of the seeded species was the R. McKimm 98 site.

Since some of the agricultural crops (ie. bean, corn and potato) grown on these soils will show salt stress below 4 dS/m, soil salinity status will be assigned according to Table 6.2.2.B below.

Table 6.2.2.B: Criteria for assigning soil salinity status.
(modified slightly from Brady, 1990 and Neufeld, (1980)).

SOIL	Common pH	EC_{sat} (dS/m)
moderately saline	<6.5	2 - 4
saline	<8.5	4 - 8
very saline	<8.5	>8
saline-sodic	<8.5	>4
sodic	>8.5	<4

Only two sites, the R. & T. Harris 99 and the R. McKimm 98, had soil salinity levels (EC_{sat}) that might have reduced performance of the seeded species. Red clover and orchard grass are sensitive to soil salinity levels greater than 1.5 dS/m, timothy and annual ryegrass are moderately sensitive (tolerate 2-4dS/m), Chewing's, red and tall fescues are moderately tolerant (4-8dS/m) (United States Salinity Laboratory Web page; www.ussl.usda.gov). The site having the highest exchangeable sodium, R & T Harris 99, had a level of exchangeable sodium that was well below 15% of the cation exchange capacity.

Conventionally, pH is measured on a 1:1 slurry and EC on a saturated paste extract. However, in this study, pH was measured using a 1:2 soil:distilled water suspension and EC was measured from the supernatant that was filtered off of 1:2 soil:distilled water suspension. In both cases, the suspension or extract here would be more 'dilute' than if conventional methods were followed.

Since grasses have a relatively low Ca demand and the soils of the Delta are fine textured and relatively young, Ca deficiency would be highly unlikely.

Levels of available P and K were found to be high enough that application would only be recommended to achieve a starter effect for annual cash crops (Neufeld, 1980). Applications of Mg are not recommended for soils containing levels higher than 99 ppm soil (Neufeld, 1980). Most sites had adequate soil quality to ensure success of the seed mix. Some fields had areas where the seed mix failed to establish successfully. These areas were considered anomalies and were sampled separately in order to identify the detrimental soil factor.

6.2.3. The Relationship Between Plant Species Cover and pH and EC

Due to the natural process of soil formation of the Fraser River delta, some of its soils tend to have high levels of soluble salts and low pH (Luttmerding, 1981b). In addition, the soils are fine textured and elevations are within 0 to 3 m of sea level (high water tables) making them poorly drained. Long periods of continuous cultivation for cash cropping on these soils have led to a decline in organic matter levels, poor soil surface structure and deep soil compaction. One objective of a grassland set-aside is to improve soil tilth or structure. As discussed in section 5.3.3, any areas showing noticeably poor growth of the DF&WT seeded species were sampled separately in order to identify the major soil factor(s) affecting grass performance. Since the intensity of sampling on the anomalous sites was different in 1998 and 1999, the first part of this discussion will pertain to the 1998 data and the later part, the 1999 data. The results for the 1998 data on the anomalous areas are summarized below (Table 6.2.3.A).

In 1992, soil quality problems reported by Delta farmers included compaction, poor drainage, soil salinity, low pH and poor structure (Leonoff et al., 1992). For most crops a pH of between 5.5 and 6.5 is adequate. The natural pH of most soils of Delta is more acidic than this range. In addition, several soil series of Delta have high soluble salts within the top meter of soil. Of the 21 sites sampled for soil quality, 11 had pockets of field areas where the DF&WT seed mix had not established well. Of these 'anomalous' areas, nine had low to very low pH (J. Harris 96, R. Harris 96, Savage 96, Berney 97, Swenson 97, Kamlah 98, B. McKimm 98, R. McKimm 98 1st and 2nd year, Chahal 98). Two of the anomalous areas had unfavourably high soil salinity (R. Harris 96, Kamlah 98 1st year) and two had moderate salinity levels (J. Harris 96, B. McKimm 1st and 2nd years). Two of the sites had areas where poor growth could not be explained by unfavourable levels of salinity, pH or sodium (Chong/Guichon 96, Guichon 97). These areas are known to have standing water on them for most of the winter months. Winter flooding causes stress for many plants and can result in drowned out patches. In addition, lower areas tend to dry out last in the spring and may be cultivated when still wet. Poor drainage and untimely cultivation lead to poor soil structure and therefore, poor plant growth.

Table 6.2.3.A: Soil Quality of Anomalous Areas Compared to their Corresponding General Field Areas (1998 sampling year).

AGE	SITE	GENERAL AREAS Soil pH (1:2 soil:water)	GENERAL AREAS ECsat (dS/m)	GENERAL AREAS Sodium (meq/100g soil)	ANOMALOUS AREAS Soil pH (1:2 soil:water)	ANOMALOUS AREAS ECsat (dS/m)	ANOMALOUS AREAS Sodium (meq/100g soil)
3rd YEAR	Savage 96	5.3L-M	0.40L	0.14	5.2L	0.42L	0.13
	Chong/Guichon 96	5.9 M	0.45L	0.12	6.2M	1.36L	2.28
	J. Harris 96	5.9M	1.02L	5.00	4.7L	6.69H	6.88
	R. Harris 96	6.0M	0.42L	0.58	4.4L	24.51VH	14.8
2nd YEAR	Berney 97	5.2L	1.57L	0.90	5.2L	1.49L	1.40
	Guichon 97	5.9M	1.10L	0.58	5.9M	4.41H	2.00
	Swenson 97	5.4L	0.66L	0.30	4.8L	1.60L	0.63
	[1]Kamlah 98	5.8M	1.67L	-	5.0L	7.65H	8.00
	[1]B. McKimm 98	5.6M	2.17M	-	5.1L	7.86H	4.75
	[1]R. McKimm 98	5.2L	2.25M	-	5.0L	1.41L	3.75
1st YEAR	Chahal 98	5.1L	1.34L	0.75	4.8L	2.25M	0.78
	[1]Kamlah 98	6.1M	1.20L	0.1.28	5.6M	14.39VH	8.00
	[1]B. McKimm 98	5.7M	1.62L	0.90	5.8M	7.99H	4.75
	[1]R. McKimm 98	4.5L	3.03M	1.78	4.2VL	6.03H	3.75

[1] Kamlah 98, B. McKimm 98 and R. McKimm 98 sites were sampled as 1st and 2nd year sites in 98 and 99 respectively.

Soil quality indicators are ranked according to the requirements of grasses and common field crops of the area as follows: VL=very low, L=low, M=moderate, H=high, VH=very high, XH=extremely high

The effect of poor soil quality on the composition of the plant canopy can be seen by comparing the canopy composition by percent cover for normal field areas (Figure 6.2.3.A) to that for the anomalous areas (Figure 6.2.3.B). In general, poor soil quality leads to an increased proportion of cover by weeds and bare ground and a decreased amount of seeded species.

Figure 6.2.3.A: Percent Cover by Seeded and Weed species, Litter and Bare Ground Across Areas of Normal Growth (1998 sampling year).

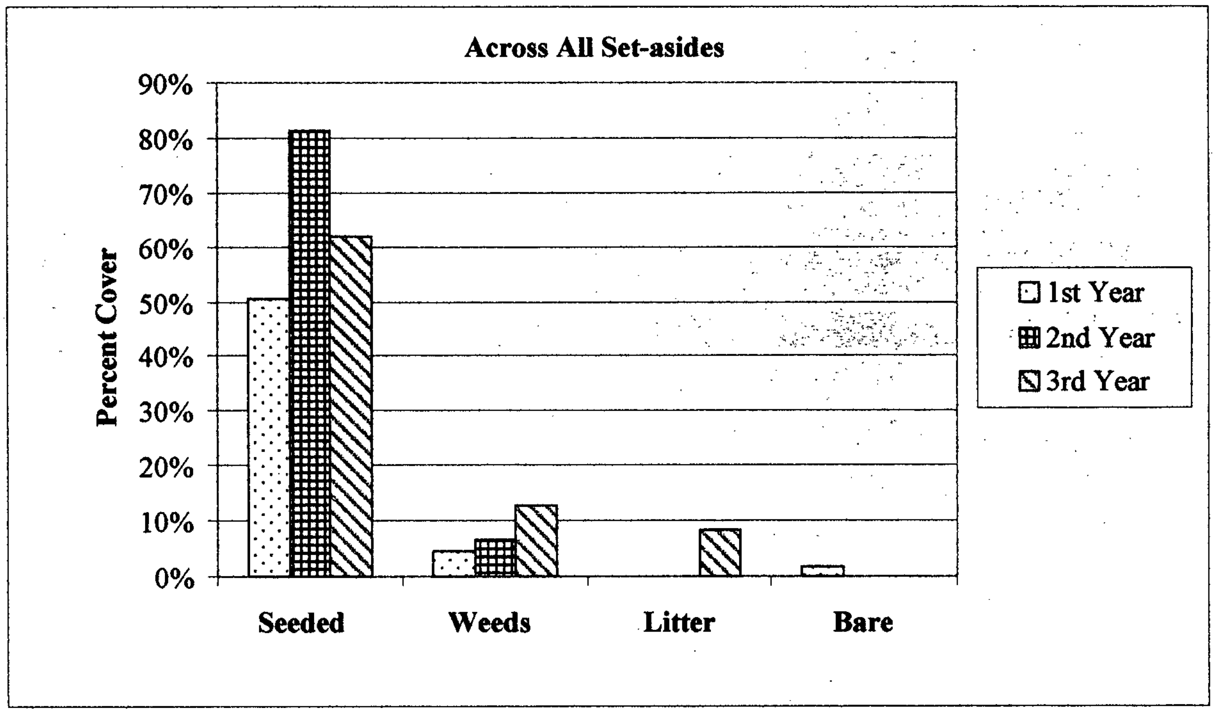
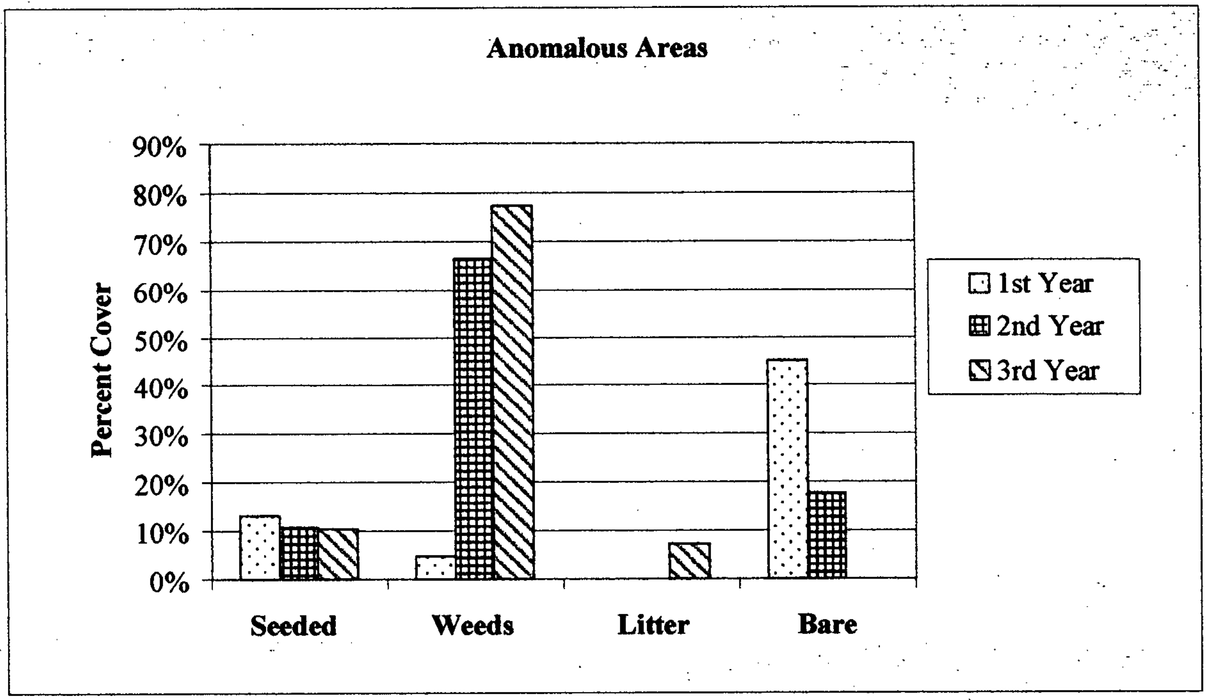


Figure 6.2.3.B: Percent Cover by Seeded and Weed species, Litter and Bare Ground Across Areas of Poor Growth (1998 sampling year).



In 1999, the anomalous areas of the Berney 97, R. McKimm 98, B. McKimm 98 and Kamlah 98 sites were sampled again. This time, the affected area was divided into quadrants and 12 samples of cover and soil quality were collected. In each quadrant, corresponding plant and soil samples were collected from areas having less than 10%, approximately 50% and approximately 100% cover by seeded species. Multiple linear regression analysis was run using both Braun-Blanquet Cover-abundance Ranks and actual percent covers in order to determine which soil quality factor (soil salinity or low pH), had a stronger negative effect on the establishment of the seeded species. For the analysis of Braun-Blanquet cover-abundance ranks the regression equation was $\hat{Y}_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3$ where X_1 is pH, X_2 is EC and X_3 is pH*EC. The regression analyses of timothy and short fescue with pH and EC had p values of 0.0070 and 0.0889 respectively. Soil salinity was found to be the most important independent variable for timothy, while pH had a stronger effect on short fescue. However, when the multiple regression was based on percent cover, the regression equation for timothy and short fescue had p values of 0.0556 and 0.0645 respectively. Although the regression equations were not significant for any other species, when total cover of all seeded species was analysed, the regression equation was significant at p=0.0773. EC was the most important variable affecting cover for timothy, short fescue and seeded species as a whole. For this analysis the regression equation used was $\hat{Y}_i = b_0 + b_1X_1 + b_2X_2$ where X_1 is pH and X_2 is EC, since there were no interactions between pH and EC.

Each individual species of the DF&WT seed mix performed differently on each area of poor soil quality. For the monitoring done in 1998, on average, tall fescue was the most successful at colonising anomalous sites. It was present on 9 of the 12 areas (75%) onto which it was seeded. Orchard grass was present on 20% of the anomalous areas on which it was seeded. Short fescue, timothy and red clover were found on 27%, 33% and 33% (respectively) of the anomalous sites on which they were seeded. For 1999, presence of the seeded species can be broken down over areas of the anomalies having 0%, 50% and 100% cover by the DF&WT mix (Table 6.2.3.B). The results for presence of each species at each EC level do not follow the reported tolerance levels. This may be an indication of either varietal differences or a more complex interaction of environmental factors.

Table 6.2.3.B: Presence of Seeded Species in Anomalous Areas (1999 sampling year).

% Cover by DF&WT mix	Average ECsat (dS/m)	% of quadrats having each species present †					
		TF	SF	Ti	RG	OG	RCl
Less than 10	5.77	25	0	12	0	0	0
Approx. 50	5.25	100	2	19	0	0	19
Approx. 100	2.38	100	25	100	12	69	56
Reported tolerance to EC (dS/m)		4-8	4-8	2-4	2-4	1.5	1.5

† TF=tall fescue, OG=orchard grass, Ti=timothy, SF=short fescues, RCl=red clover, RG=rye grass Reported tolerance to EC was taken from (United States Salinity Laboratory Web page; www.ussl.usda.gov)

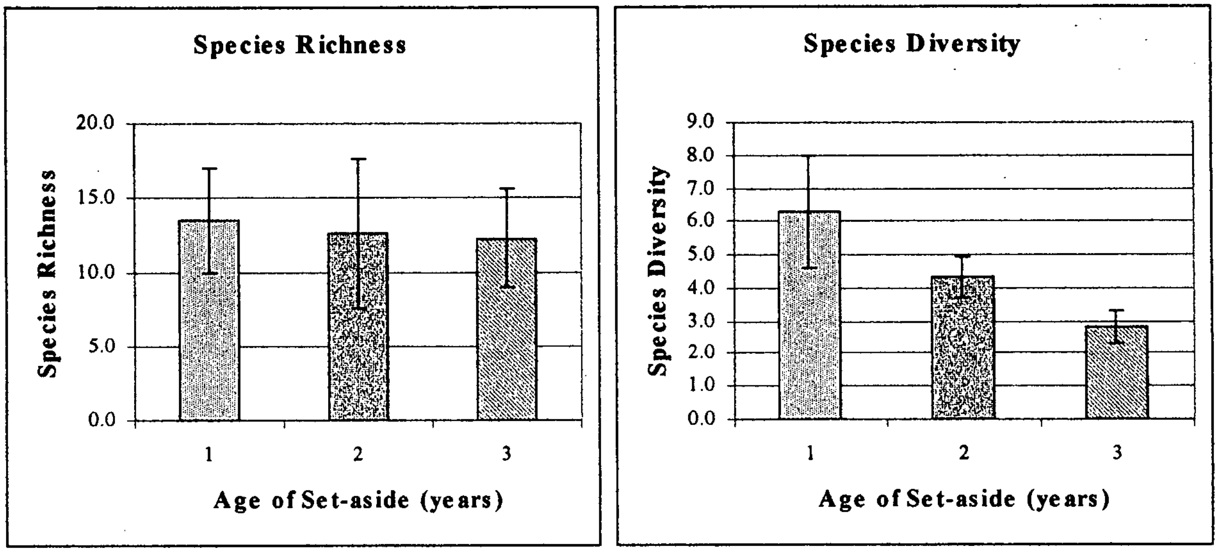
Once again, tall fescue was found to be the most successful species on anomalous areas. According to reported tolerances of each species to soil salinity (Table 6.2.3.B), tall fescue and short fescue should have no problem with the observed EC levels. EC levels were closer to, but still below threshold levels for timothy and ryegrass. Perhaps timothy performed better than expected due to its ability to tolerate both very dry and very wet conditions. Orchard grass and red clover established poorly as expected.

Non-seeded species (weeds) colonized areas where the DF&WT mix established poorly. These plant species included grasses and broad-leaved species that may be native or naturalized (see Appendix 2 for a complete list of weeds found in anomalous areas). Although many of these species are weeds of arable land, none are considered noxious in the Fraser Valley. It is also worth noting that small areas not colonized by planted grasses do provide some habitat value not related to grasslands. Although controversial, in Britain, natural revegetation is one method for establishing a set-aside (Andrews & Rebane, 1994). In Delta, natural revegetation is not as desirable because these set-asides are relatively short term; therefore, fast canopy establishment for both soil conservation/remediation and for creating wildlife habitat is preferred. In addition, because set-asides in Delta are returned to cultivation after 3-5 years, creating large weed seed banks may be a problem with natural revegetation.

6.2.4. The Effect of Set-aside Age on Plant Canopy Characteristics

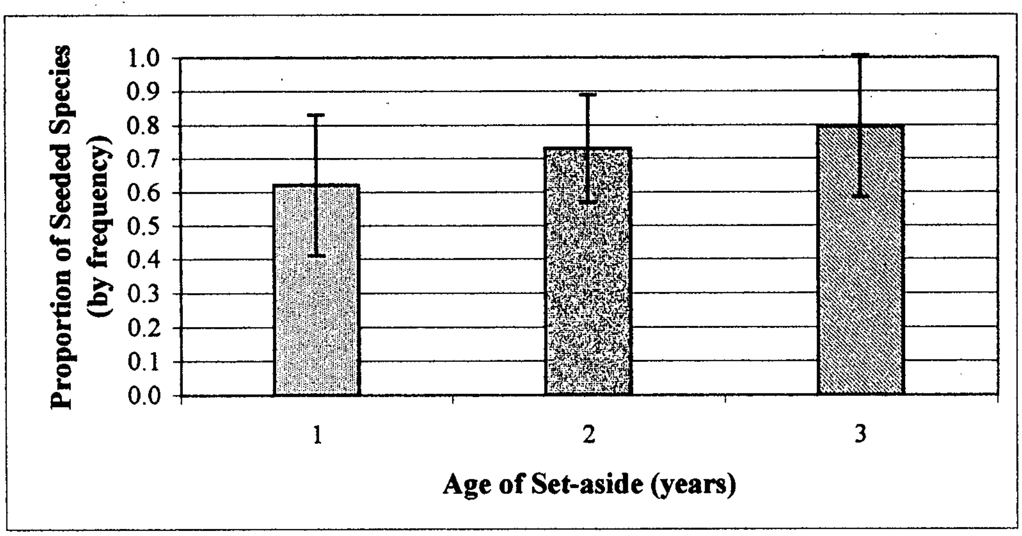
Generally, as a grass stand matures, annual species are replaced by perennial species and perennial species increase in size. As a result, in the initial year of a set-aside there will be many small individuals. As perennial plants increase in size there will be fewer, larger individuals relative to a first year site. This means that as a grass stand matures a decrease in diversity (the average number of species per quadrat) occurs. Figure 6.2.4.A shows the decrease in diversity observed on the DF&WT set-asides over three years. Plant diversity is an important characteristic of a grassland set-aside. Diverse plant stands will provide both a variety of food sources and a variable canopy structure for wildlife inhabiting and/or making use of the set-aside. Figure 6.2.4.B shows that as a set-aside matures the proportion of seeded species (based on species frequencies) relative to weeds or non-seeded species in a quadrat increases. While differences in the proportion of seeded species over set-aside age are within the standard deviation of the mean, some of the decrease in diversity occurs due to a loss of weed species. Figure 6.2.4.A shows, that over the first three years of a set-aside, the total number of species on a site (richness) remains within one standard deviation of the mean.

Figure 6.2.4.A: Species Richness and Diversity over Set-aside Age.



Error bars show +/- one standard deviation of the mean.

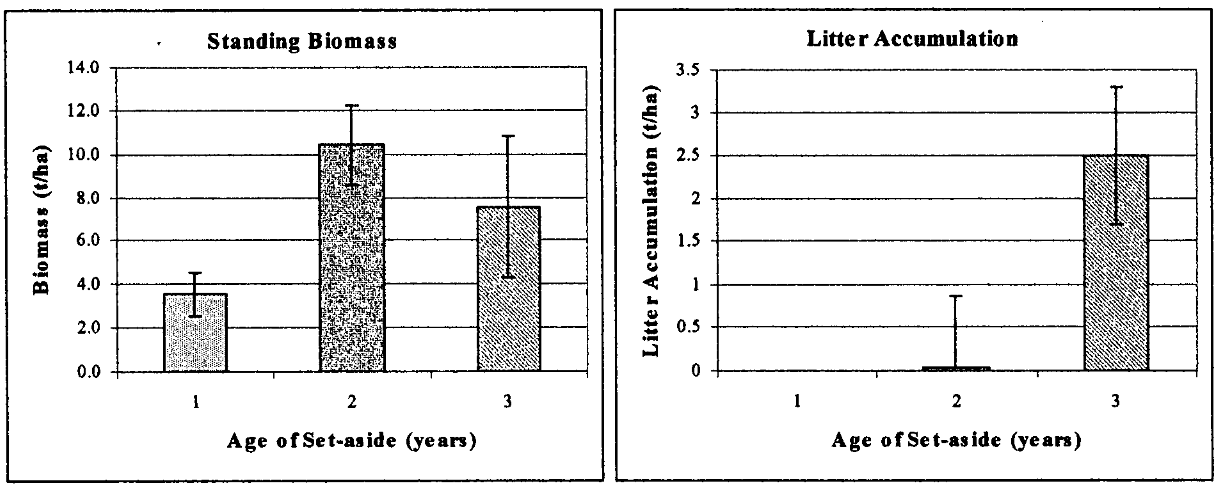
Figure 6.2.4.B: Canopy Composition Over Set-aside Age.



Error bars show +/- one standard deviation of the mean.

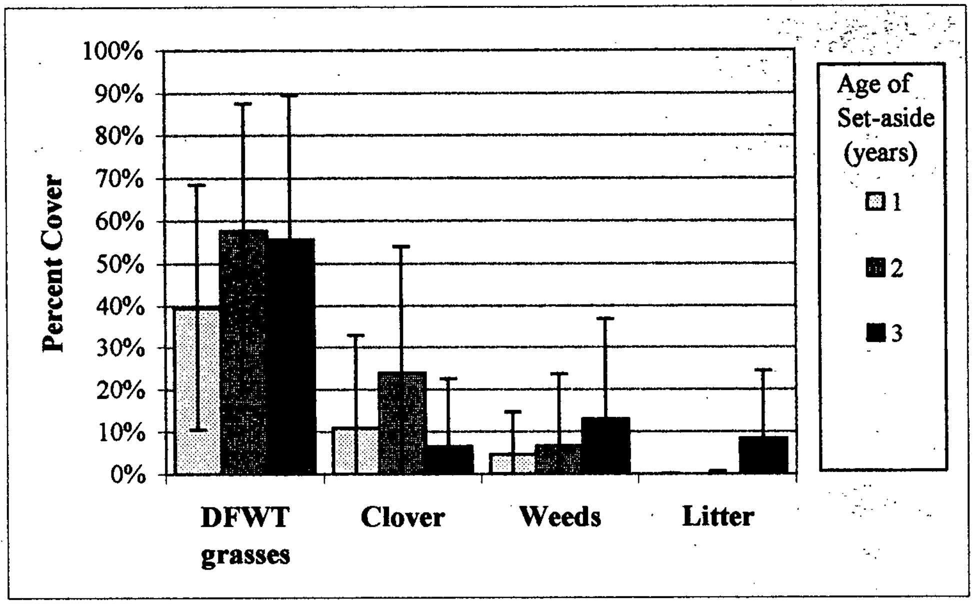
The biomass productivity of a set-aside indicates characteristics of habitat and soil. Grassland set-asides are valuable habitat for many wildlife species because they provide food and shelter. In winter months, lodged and decomposing grasses (litter) provide shelter, nesting material and protection from predators for small mammals, such as voles. Biomass becomes soil organic matter as both roots and shoots senesce. As expected there is an accumulation of litter as the grass stands age (Figure 6.2.4.C). For the first two years, litter accumulation is negligible, while in the third year there is a significant increase in litter from the decomposing grasses and clover of the second year. There are several possible factors responsible for the relatively high biomass, in the second year of the set-asides (Figure 6.2.4.C). Heavy invasions of volunteer red clover, which is a high yielding species, were common in second year sites (Figure 6.2.4.D). The high level of litter accumulations after the second year may also contribute to lower grass productivity, or the abundance and frequencies of individual planted species, in the third year. Therefore, biomass is expected to increase as a set-aside establishes and then settle into a relatively stable productivity.

Figure 6.2.4.C: Standing and Litter Biomass over Set-aside Age.



Error bars show +/- one standard deviation of the mean.

Figure 6.2.4.D: Percent Cover of Categories as the Set-asides Age.

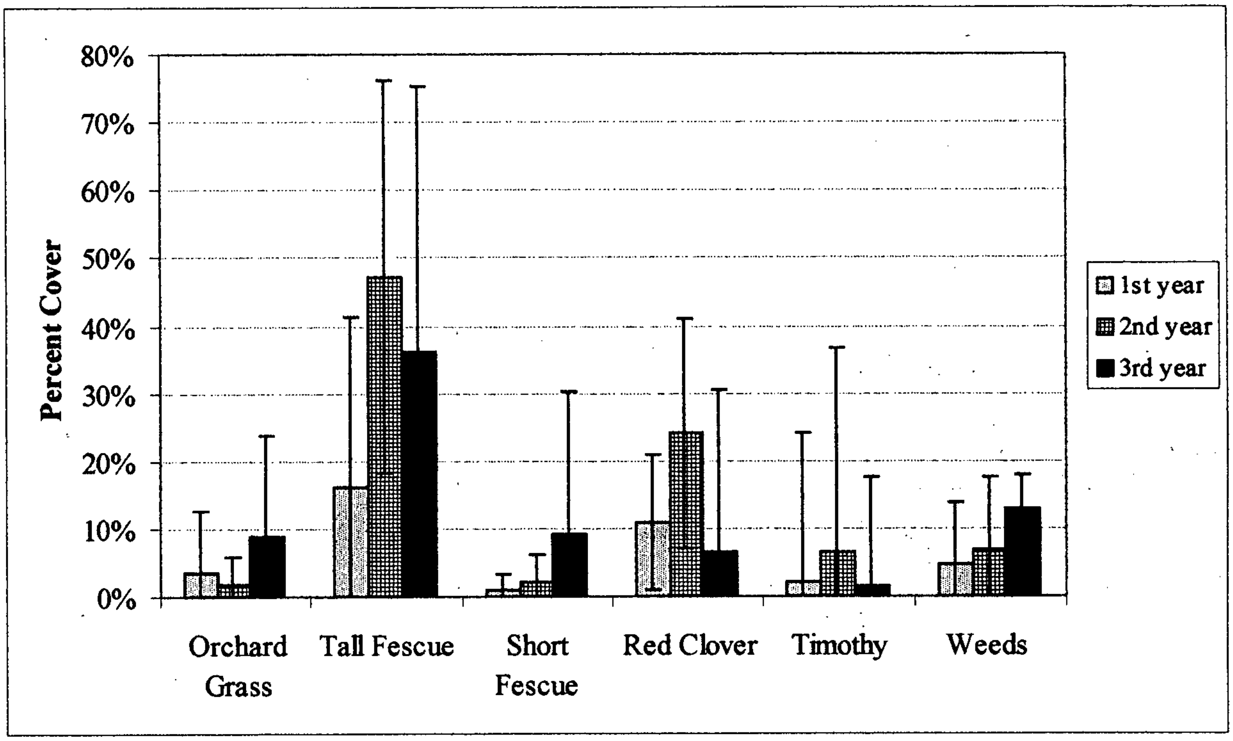


*** The increase in weeds is due to a high percentage of samples coming from poor fields in the 2nd and 3rd year sites- see discussion below.**
Error bars show +/- one standard deviation of the mean.

Figure 6.2.4.E shows percent cover of species across all set-asides. It appears that the percent cover of tall fescue, timothy and red clover peak in the second year of a set-aside, that short fescue and weeds slowly increase in percent cover and that orchard grass decreases in the second year and peaks in the third year of a set-aside. The apparent increase in weeds over the years is misleading due to the proportion of samples from unusually poor sites that were entered into the set-aside program in 1996 (Savage, Harris) and 1998 (Kamlah, R. McKimm). For the first, second and third year sites, 10%, 17% and 21% of samples respectively came from poor sites. In this light, tall fescue and timothy seem to perform well. However, this fact may make conclusions about trends in percent cover of orchard grass and short fescue unreliable. For example, is the slow increase of

cover of these two species due to poor soil conditions or are these species simply slower to establish? In addition, the differences are negligible when compared to the variation in the data (represented by the error bars).

Figure 6.2.4.E: Percent Cover of Species as the Set-aside Ages.



Error bars show +/- one standard deviation of the mean.

6.2.5. The Effect of Site on Plant Canopy Conditions

Since the multi-field study was based on a sample of fields chosen from the monitoring of the Set-aside Program, fields varied in nurse crop, time and method of seeding, weather conditions during germination, fertilizer regime etc. Variable levels of soil quality among fields further increased the complexity of analyzing this data. Table 6.2.5.A divides all the sites monitored into set-aside age, sampling year and cohort. In order to assess the effect of site on plant canopy characteristics, a one way analysis of variance was run on each cohort within each sampling year to determine if the within field variance was greater than the between field variance. Results are summarized in Table 6.2.5.B on the next two pages.

Table 6.2.5.A: Sites of Multi-field Study by Age, Sampling Year and Establishment Year.

SAMPLE YEAR	1st Year Sites	2nd Year Sites	3rd Year Sites
1998	98 COHORT	97 COHORT	96 COHORT
	Reynolds (98) – barley	Singh WI (97) – none	Montgomery (96) – barley
	Kamlah (98) - annual ryegrass	Singh Lad (97) – none	Savage (96) – barley
	R. McKimm (98) –none	Guichon (97) – barley	R. Harris (96) – annual ryegrass
	B. McKimm (98) –none	Montgomery (97) – oats	Chong/Guichon (96) –annual ryegrass
	Chong (98) – none	Swenson (97) – none	
	Chahal (98) – oats	Berney (97) – oats	
1999	99 COHORT	98 COHORT	97 COHORT
	Reynolds (99) – barley	Reynolds (98) – barley	Singh Lad (97) – none
	Montgomery (99) – oats	Kamlah (98) – annual ryegrass	Guichon (97) - barley
	Harris (99) – barley	R. McKimm (98) – none	Berney (97) - oats
	Chong WI (99) –annual ryegrass	B. McKimm (98) – none	
		Chong (98) – none	
		Chahal (98) – oats	

Table 6.2.5.B: Within Field Variance and Between Field Variance of Percent Cover by Cohort and Sampling Year.

Sampling Year	Cohort	Species	Site	Nurse Crop	Percent Cover†	p-value
1998	1996	**Seeded**	Chong/Guichon (96)	Ryegrass	61.2 a	0.0001
			Montgomery (96)	Barley	62.6 a	
			R. Harris (96)	Ryegrass	15.6 b	
			Savage (96)	Barley	17.6 b	
		Weeds	R. Harris (96)	Ryegrass	69.2 a	0.0001
			Savage (96)	Barley	38.0 b	
			Chong/Guichon (96)	Ryegrass	1.6 c	
			Montgomery (96)	Barley	6.5 c	
1998	1997	**Seeded**	Berney (97)	Oats	110.7 a	0.0001
			Montgomery (97)	Oats	109.2 a, b	
			Guichon (97)	Barley	87.1 a, b, c	
			Singh Lad (97)	None	79.2 b, c	
			Swenson (97)	None	68.6 c	
			Singh WI (97)	None	68.2 c	
		Weeds	Swenson (97)	None	13.4 a	0.0395
			Singh WI (97)	None	7.1 a	
			Berney (97)	Oats	3.2 a	
			Guichon (97)	Barley	1.6 a	
			Singh Lad (97)	None	0.7 a	
			Montgomery (97)	Oats	0.08 a	
1998	1998	**Seeded**	Chong (98)	None	76.9 a	0.0001
			B. McKimm (98)	None	69.8 a	
			Kamlah (98)	Ryegrass	65.9 a	
			Chahal (98)	Oats	34.1 b	
			Reynolds (98)	Barley	33.7 b	
			R. McKimm (98)	None	28.8 b	
		Weeds	R. McKimm (98)	None	6.7 a	0.0115
			Chong (98)	None	1.8 a, b	
			Chahal (98)	Oats	0.3 b	
			B. McKimm (98)	None	0.3 b	
			Kamlah (98)	Ryegrass	0.2 b	
			Reynolds (98)	Barley	0.1 b	

Continued on next page

Table 6.2.5.B continued: Within Field Variance and Between Field Variance of Percent Cover by Cohort and Sampling Year.

Sampling Year	**Cohort**	**Species**	**Site**	**Nurse Crop**	**Percent Cover†**	**p-value**
1999	1997	**Seeded**	Berney (97)	Oats	90.3 a	0.0195
			Singh Lad (97)	None	86.6 a, b	
			Guichon (97)	Barley	69.7 b	
		Weeds	Guichon (97)	Barley	12.3 a	0.0171
			Berney (97)	Oats	0.0 b	
			Singh Lad (97)	None	0.0 b	
1999	1998	**Seeded**	Chahal (98)	Oats	87.0 a	0.1130
			B. McKimm (98)	None	85.8 a	
			Chong (98)	None	80.3 a	
			Reynolds (98)	Barley	76.8 a	
			R. McKimm (98)	None	66.5 a	
			Kamlah (98)	Ryegrass	58.1 a	
		Weeds	R. McKimm (98)	None	27.0 a	0.0002
			Kamlah (98)	Ryegrass	23.3 a, b	
			Chahal (98)	Oats	1.5 b, c	
			Reynolds (98)	Barley	0.6 b, c	
			B. McKimm (98)	None	0.3 c	
			Chong (98)	None	0.2 c	
1999	1999	**Seeded**	Chong WI (99)	Ryegrass	82.2 a	0.0001
			Reynolds (99)	Barley	47.8 b	
			Montgomery (99)	Oats	45.0 b	
			Harris (99)	Barley	19.6 c	
		Weeds	Harris (99)	Barley	28.6 a	0.0001
			Reynolds (99)	Barley	7.5 b	
			Montgomery (99)	Oats	1.0 b	
			Chong WI (99)	Ryegrass	0.04 b	

† Percent covers followed by same letters are not significantly different at alpha=0.05 using Bonferroni's Multiple Range test.

Excluding the 1998 cohort sampled in 1999, each sampling year and cohort combination has a significant site effect on seeded species ($p<0.10$). The effect of site on weeds is always significant at this alpha level. This reflects the significant variation due to nurse crop, time and method of seeding, weather conditions during germination, fertilizer regime and soil quality. Given this large amount of variation between sites, any further conclusions regarding effect of nurse crop or establishment year would be dubious.

6.2.6. Conclusions for Multi-field study

Monitoring was done on a sample of 21 fields taken from the total enrolled in the Set-aside Program in 1998 and 1999. For the most part, soil quality (pH, EC, SAR, P, K, Ca and Mg) was not likely to affect growth of the seeded species. Low pH may have been a problem on the R. McKimm 98 site and soil salinity may have been an issue on the R. & T. Harris 99 and the R. McKimm 98 sites.

In a regression analysis of areas with poor growth of seeded species, soil salinity proved to be the stronger variable for timothy and the seeded species as a whole, while short fescue may have been effected by either pH or EC depending on the method used for measuring cover. Where neither pH nor EC was a problem and poor growth still occurred, winter flooding and crop drown out are suspected. As a set-aside matured, percent cover by seeded species did not improve in anomalous areas as it did in general areas. These anomalous areas are covered predominantly by weeds or no plant matter at all. A reasonable level of soil quality with respect to drainage, pH and salinity is necessary to ensure that a grassland set-aside provides habitat and soil conservation. Ideally, site preparation previous to establishing a grassland set-aside that would improve these anomalous areas would include the upgrading or installation of subsurface drains and/or laser levelling. To prevent field ponding in the absence of these improvements, the installation of small surface ditches would be necessary to maintain the productivity of the field.

As a set-aside ages, plant canopy characteristics change. There is a general decrease in diversity due to the increasing size of individual plants and a subsequent decrease in number of individuals. Over three years, species richness stays relatively stable. Biomass of the seeded species peaks in the second year due to heavy invasions of red clover and a build up of litter at the end of the second year, which suppresses some of the third year's production. When based on frequency, the proportion of seeded species relative to weeds increases as a set-aside ages. However, when percent cover is analyzed, weeds seem to increase over time due to an increasing proportion of poor sites occurring in the sample over three years.

Although species composition of a set-aside varies over three years, some general observations regarding species performance can be made. The order of seeded species from most dominant to least dominant seemed to follow the trend of tall fescue>>red clover>>short fescues≥orchard grass≥timothy. Tall fescue was by far the most dominant species found on the set-asides. Red clover was next to tall fescue, especially in the second year of the set-aside. The short fescues appeared to be next in terms of dominance while orchard grass and timothy seemed least dominant. Likely factors contributing to this order include proportion of the mix devoted to a species, specific seed weight, individual species germination requirements, weather conditions at time of seeding and throughout the set-aside period, soil quality, interspecific competition, water fowl grazing events and method of measurement.

Chapter 7 RECOMMENDATIONS AND FURTHER RESEARCH

Delta's flat topography and mild climate has been especially favorable for the production of processing crops. Provided soil moisture content was not excessive, heavy harvesting equipment easily navigated fields. The mild climate allowed for slower ripening of crops and thus a larger window of opportunity for harvesting. By 1992, 56% of the farmland in Delta was dedicated to the production of only four crops; potatoes, peas, corn and beans (Leonoff et al., 1992), all of which, excluding some potatoes for fresh consumption, were for the local processing market. Unfortunately, in 1995 Pillsbury closed the Fraser Valley fruit and vegetable processing plant. Farmers searched for new markets for their peas, beans and corn. In many situations, since the processing market for potatoes remained, the number of years between potato crops simply got smaller and smaller. And yet, maintaining a diverse crop rotation that includes grass is particularly important to soils such as those in Delta.

Farmers may participate in the DF&WT's Grassland Set-aside Program in order to maintain a sustainable crop rotation upon soils that are already productive (i.e. the small plot study sites), or to try to restore degraded soil to an acceptable level of productivity. If a farmer's primary goal is to maintain a sustainable crop rotation on a productive site, then the DF&WT mix will perform well. However, over the period of this study, sites with areas of poor growth of the seeded species did not improve. Therefore, if reclamation is the goal, the objectives of the set-aside program may be compromised in areas of some fields.

In order to ensure that set-asides both provide wildlife habitat and improve or maintain soil quality, an assessment of the need for initial remedial practices (ie. sub-soiling, laser-leveling, installation of sub surface drainage) should be done prior to seeding. Soil quality should be evaluated for soil chemical status (pH, EC, N, P, K, Ca, Mg, Na) and sub-surface soil compaction. In addition, areas having ponded water during winter should be identified. The need for sub-soiling, sub-surface soil drainage, soil laser leveling, lime and manure applications, or other possible restorative measures should also be evaluated.

In some cases, economic or related land tenure problems (i.e. short-term lease policy) will prevent necessary remedial practices. In these situations, a "restoration mix" composed of grass species that tolerate wet and saline conditions could be developed and seeded in lieu of the standard DF&WT seed mix. Species might include timothy, tall fescue, creeping bent grass (*Agrostis stolonifera*), meadow foxtail (*Alopecurus pratensis*) and reed canary grass (*Phalaris arundinaceae*). Consideration should be given to the contribution of these species to wildlife habitat and soil conservation as well as the availability of seed and subsequent weed potential. However, as the DF&WT mix in this study was unable to remediate poor soil conditions on set-asides, it is unlikely that these tolerant species will perform well enough to correct the poor soil conditions. While a restoration mix may provide cover, it is unlikely to have the required impact on soil quality. Under such circumstances the soil and wildlife habitat conservation objectives of the grassland set-aside program may become compromised.

In terms of the DF&WT mix itself, tall fescue dominates the stand with the exception of the 2nd year in which the canopy is dominated by red clover and tall fescue. Red clover grows fast early in the spring of the second year and dies in mid to late summer smothering out shorter plant species such as the short fescues. It is uncertain whether the large amount of cover by clover is due only to seed from the seed mix or a residual pool of red clover seeds in the weed seed bank (or both). If the major source of red clover is the seed mix, and considering that red clover makes up only 2% of the seed mix (by weight), substituting red clover for a less aggressive species, white clover for example, may be more desirable.

Tall fescue is also a very successful species on the grassland set-asides. The number of germinated seeds predicted, based on reported germination rates and seeding rate of the '97/98 mix, is 350 germinated seeds/m^2 for tall fescue and 31 germinated seeds/m^2 for red clover. Less dominant species are short fescues (525 germinated seeds/m^2), orchard grass (751 germinated seeds/m^2) and timothy (1085 germinated seeds/m^2). In order to maintain a diverse canopy structure, consideration should be given to reducing, slightly, the proportion of tall fescue, increasing orchard grass and increasing or replacing timothy.

For the purpose of monitoring fields in the DF&WT Set-aside program the following protocol is recommended. First, the soil quality of fields accepted into the program should be assessed. Anomalous areas should be identified by visual observation of the field in spring (when areas of ponded water are obvious) and by conversations with the grower <u>before</u> sowing. These areas should be sampled separately for subsoil compaction and aggregate stability; salinity, pH, and cation exchange capacity; exchangeable Na, K, Ca and Mg, and available P. The soil assessment will reveal what remedial practices (installation of sub-surface drains, laser leveling, sub-soiling, lime application) are needed to achieve acceptable establishment conditions for the set-aside mix. Sites having large areas of poor soil conditions may be seeded to a 'restoration' mix to ensure adequate plant cover.

Alternatively, the field may be seeded to the DF&WT mix and anomalous areas may be re-seeded to the 'restoration' mix if the DF&WT mix does not establish by fall. In their first year, sites should be sampled for biomass and percent cover in the fall, while for older sites sample collection should be done in late July to early August. Comparisons of the performance of specific species and the seed mix as a whole can be made among sites in the same establishment year.

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APPENDIX 1 – A.N.O.V.A tables

Small Plot Study

A.N.O.V.A Table for Figure 6.1.3.A MWD Over Two Years and Three Nurse Crop Treatments.

Source of Variation	DF	SS[2]	F-value[1]	P-value
Block	3	0.2212	1.23	0.3538
Nurse	2	0.3358	1.25 (E1)	0.3523
Error 1	6	0.8075	no test	no test
Year	1	0.07042	1.18	0.3063
Nurse x Year	2	0.2058	1.72	0.2331
Error 2	9	0.5387	no test	no test

1 Tested over error 2 unless otherwise indicated.
2 SS was calculated on raw data in g/0.25m^2.

A.N.O.V.A Table for Figure 6.1.4.A Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Establishment Year, August 1998).

Category	Source of Variation	DF	SS[3]	F-value[1]	P-value
Seeded	Block	3	51.4583	0.26	0.8546
	Nurse	2	898.0833	6.70	0.0296
	Error 1	6	401.9167	0.88 (E2)	0.5389
	Error 2	12	915.5000	no test	no test
Weed	Block	3	572.4583	1.81	0.2460
	Nurse	2	15046.5833	71.26	0.0001
	Error 1	6	633.4167	0.72 (E2)	0.6385
	Error 2	12	1748.5000	no test	no test
Nurse	Block	3	3093.6667	0.94	0.4797
	Nurse	2	248122.5833	112.54	0.0001
	Error 1	6	6614.0833	5.82 (E2)	0.0048[2]
	Error 2	12	2271.0000	no test	no test
Total	Block	3	4366.6667	1.11	0.4143
	Nurse	2	127205.0833	48.69	0.0002
	Error 1	6	7837.5833	4.69 (E2)	0.0111[2]
	Error 2	12	3342.0000	no test	no test

1 Tested over error 1 unless otherwise indicated. Error 1 is Block x Nurse, Error 2 is sampling error.
2 SS was calculated on raw data in g/0.25m^2.
See discussion on block x nurse interaction in section 6.1.6.

A.N.O.V.A Table for Figure 6.1.4.B Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Establishment Year, November 1998).

Category	Source of Variation	DF	SS[2]	F-value[1]	P-value
Seeded	Block	3	620.1704	0.60	0.6406
	Nurse	2	1283.9603	1.85	0.2367
	Error 1	6	2082.0756	0.23 (E2)	0.9598
	Error 2	12	18305.6494	no test	no test
Weed	Block	3	1585.0167	0.99	0.4600
	Nurse	2	3863.5858	3.61	0.0937
	Error 1	6	3214.7008	0.78 (E2)	0.5990
	Error 2	12	8207.3100	no test	no test
Nurse	Block	3	312.7000	0.82	0.5265
	Nurse	2	4999.0473	19.77	0.0023
	Error 1	6	758.5375	2.48 (E2)	0.0850
	Error 2	12	611.2600	no test	no test
Total	Block	3	2249.7241	0.67	0.5991
	Nurse	2	1994.7775	0.90	0.4567
	Error 1	6	6682.1574	0.34 (E2)	0.9043
	Error 2	12	39660.6444	no test	no test

Error 1 is Block x Nurse, Error 2 is sampling error.
1 Tested over error 1 unless otherwise indicated.
2 SS was calculated on raw data in g/0.25m^2.

A.N.O.V.A Table for Figure 6.1.4.C Biomass of Seeded Species, Weeds and Nurse Crop Across Three Nurse Crop Treatments (Second Season, August 1999).

Category	Source of Variation	DF	SS[2]	F-value[1]	P-value
Seeded	Block	3	23285.4583	2.08	0.2049
	Nurse	2	7004.0833	0.94	0.4425
	Error 1	6	22429.9167	0.20	0.9690
	Error 2	12	2202108.5000	no test	no test
Weed	Block	3	536.3333	1.00	0.4547
	Nurse	2	432.0000	1.21	0.3623
	Error 1	6	1072.6667	0.95	0.4959
	Error 2	12	2257.0000	no test	no test
Total	Block	3	28243.1250	2.14	0.1962
	Nurse	2	10898.0833	1.24	0.3543
	Error 1	6	26371.2500	0.24	0.9562
	Error 2	12	223605.5000	no test	no test

Error 1 is Block x Nurse, Error 2 is sampling error.
1 Tested over error 1 unless otherwise indicated.
2 SS was calculated on raw data in g/0.25m^2.

A.N.O.V.A Table for table 6.1.5.A A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Biomass of Seeded and Weed Species (Sampled August 1999).

Category	Source of Variation	DF	SS[2]	F-value[1]	P-value
Seeded	Block	3	8634.6979	2.28	0.1488
	Nurse	2	567.7500	0.11 (E1)	0.9013
	Error 1	6	16113.333	no test	no test
	Fertility	1	4069.0104	3.22	0.1065
	Fert. x Nurse	2	6043.0833	2.39	0.1472
	Error 2	9	11385.2812	no test	no test
Weed	Block	3	134.0833	1.00	0.4363
	Nurse	2	108.0000	1.21 (E1)	0.3623
	Error 1	6	268.1667	no test	no test
	Fertility	1	54.0000	1.21	0.3002
	Fert. x Nurse	2	108.0000	1.21	0.3429
	Error 2	9	402.2500	no test	no test
Total	Block	3	9708.8646	2.35	0.1408
	Nurse	2	909.7500	0.15 (E1)	0.8657
	Error 1	6	18466.9167	no test	no test
	Fertility	1	5060.5104	3.67	0.0876
	Fert. x Nurse	2	7648.0833	2.77	0.1152
	Error 2	9	12407.0312	no test	no test

Error 1 is Block x Nurse.

1 Tested on Error 2 unless otherwise stated.

2 SS was calculated on raw data in g/0.25m^2

A.N.O.V.A table for Table 6.1.5.B A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Cover of Individual Seeded and Weed Species (Sampled August 1999).

Category	Source of Variation	DF	SS	F-value[1]	P-value
OG	Block	3	5.1250	4.56	0.0333
	Nurse	2	1.0833	1.44 (E1)	0.3075
	Error 1	6	2.2500	no test	no test
	Fertility	1	3.3750	9.00	0.0150
	Fert. x Nurse	2	0.7500	1.00	0.4053
	Error 2	9	3.3750	no test	no test
TF	Block	3	2.1667	0.79	0.5304
	Nurse	2	2.0833	1.12 (E1)	0.3862
	Error 1	6	5.5833	no test	no test
	Fertility	1	1.5000	1.64	0.2328
	Fert. x Nurse	2	0.2500	0.14	0.8743
	Error 2	9	8.2500	no test	no test
SF	Block	3	1.1250	0.31	0.8175
	Nurse	2	3.2500	1.70 (E1)	0.2608
	Error 1	6	5.7500	no test	no test
	Fertility	1	15.0417	12.45	0.0064
	Fert. x Nurse	2	7.5833	3.14	0.0925
	Error 2	9	10.8750	no test	no test
Ti	Block	3	2.1250	2.04	0.1788
	Nurse	2	0.3333	1.00 (E1)	0.4219
	Error 1	6	1.000	no test	no test
	Fertility	1	0.3750	1.08	0.3258
	Fert. x Nurse	2	0.0000	0.00	1.0000
	Error 2	9	3.1250	no test	no test
RCl	Block	3	2.1667	1.24	0.3519
	Nurse	2	0.0833	0.04 (E1)	0.9565
	Error 1	6	5.5833	no test	no test
	Fertility	1	0.0000	0.00	1.00
	Fert. x Nurse	2	0.7500	0.64	0.5483
	Error 2	9	5.2500	no test	no test

1 Tested on Error 2 unless otherwise stated. Error 1 is Block x Nurse.

A.N.O.V.A table for Table 6.1.5.B *continued...* A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Cover of Individual Seeded and Weed Species (Sampled August 1999).

Category	Source of Variation	DF	SS	F-value[1]	P-value
Weed	Block	3	2.3333	1.47	0.2861
	Nurse	2	1.5833	1.97 (E1)	0.2205
	Error 1	6	2.4167	no test	no test
	Fertility	1	0.1667	0.32	0.5879
	Fert. x Nurse	2	4.0833	3.87	0.0613
	Error 2	9	4.7500	no test	no test
Total	Block	3	0.1667	0.06	0.6915
	Nurse	2	0.3333	3.00 (E1)	0.1250
	Error 1	6	0.3333	no test	no test
	Fertility	1	0.0000	0.00	1.0000
	Fert. x Nurse	2	0.0000	0.00	1.0000
	Error 2	9	1.0000	no test	no test

Error 1 is Block x Nurse.
1 Tested on Error 2 unless otherwise stated.

A.N.O.V.A Table for Table 6.1.6.A A.N.O.V.A p-values and Means Showing The Effect of Fertility Treatment on Biomass (t/ha) of Seeded and Weed Species (Sampled August 1999).

Category	Source of Variation	DF	SS	F-value	P-value
DF&WT	Regression	1	157058.2633	61.97	0.0001
	Residual	70	177420.3448	no test	no test
Clover	Regression	1	32955.6242	4.38	0.0419
	Residual	46	346080.3758	no test	no test
Weed	Regression	1	45664.4589	215.51	0.0001
	Residual	70	14832.5272	no test	no test
Nurse	Regression	1	174083.8952	44.52	0.0001
	Residual	22	86017.4382	no test	no test

A.N.O.V.A Table for Cover Only for Table 6.1.6.B. Summary of Small Plot Results; Effect of Nurse Crop and Fertility Treatments on Biomass and Percent Cover (1998 data pre-barley harvest). For Biomass see A.N.O.V.A table for Table 6.1.5.A above.

Category	Source of Variation	DF	SS	F-value[1]	P-value
Seeded	Block	3	3.7917	2.12	0.1995
	Nurse	2	3.0833	2.58	0.1553
	Error 1	6	3.5833	0.84 (E2)	0.5605
	Error 2	12	8.5000	no test	no test
Weed	Block	3	1.8889	2.78	0.1329
	Nurse	2	36.5833	26.88	0.0010
	Error 1	6	4.0833	1.63 (E2)	0.2209
	Error 2	12	5.0000	no test	no test
Total	Block	3	1.6667	2.50	0.1565
	Nurse	2	22.3333	50.25	0.0002
	Error 1	6	1.3333	0.67 (E2)	0.6785
	Error 2	12	4.0000	no test	no test

Error 1 is Block x Nurse, Error 2 is sampling error.

1 Tested on error 1 unless otherwise indicated.

A.N.O.V.A Table for Cover Only for Table 6.1.6.C. Summary of Small Plot Results; Effect of Nurse Crop and Fertility Treatments on Biomass[1] and Percent Cover[2] (1999 data). For Biomass see A.N.O.V.A table for Table 6.1.5.A above.

Category	Source of Variation	DF	SS	F-value[1]	P-value
Seeded	Block	3	0.1667	0.50	0.6915
	Nurse	2	0.3333	3.00 (E1)	0.1250
	Error 1	6	0.3333	no test	no test
	Fertility	1	0.0000	0.00	1.0000
	Fert. x Nurse	12	0.0000	0.00	1.0000
	Error 2	9	1.0000	no test	no test
Weed	Block	3	2.3333	1.47	0.2861
	Nurse	2	1.583	1.97 (E1)	0.2205
	Error 1	6	2.4167	no test	no test
	Fertility	1	0.1667	0.32	0.5879
	Fert. x Nurse	12	4.083	3.87	0.0613
	Error 2	9	4.750	no test	no test
Total	Block	3	0.1667	0.50	0.6915
	Nurse	2	0.3333	3.00 (E1)	0.1250
	Error 1	6	0.3333	no test	no test
	Fertility	1	0.0000	0.00	1.00
	Fert. x Nurse	12	0.0000	0.00	1.00
	Error 2	9	1.0000	no test	no test

Error 1 is Block x Nurse.

1 Tested on Error 2 unless otherwise stated.

Multi-field Study

A.N.O.V.A Table for Regression Analysis on Braun-Blanquet Cover-abundance Ranks on Anomalous Areas (1999 data).

Category	Source of Variation	DF	SS	F-value	P-value
Timothy	Regression	3	16.3622	4.59	0.0070
	Residual	44	52.3044	no test	no test
Short Fescue	Regression	3	2.1695	2.31	0.0889
	Residual	44	13.7472	no test	no test
Tall Fescue	Regression	3	15.9822	1.20	0.3224
	Residual	44	195.9970	no test	no test
Red Clover	Regression	3	10.4005	1.74	0.1737
	Residual	44	87.9120	no test	no test
Orchard Grass	Regression	3	4.5020	1.98	0.1314
	Residual	44	33.4147	no test	no test
DFWT grasses	Regression	3	23.7729	1.58	0.2066
	Residual	44	220.0396	no test	no test
Weeds	Regression	3	9.2431	0.25	0.8577
	Residual	44	532.5694	no test	no test

A.N.O.V.A Table for Regression Analysis on Percent Cover on Anomalous Areas (1999 data).

Category	Source of Variation	DF	SS	F-value	P-value
Timothy	Regression	2	405.6906	3.08	0.0556
	Residual	45	2961.0594	no test	no test
Short Fescue	Regression	2	3.7816	2.91	0.0645
	Residual	45	29.1975	no test	no test
Tall Fescue	Regression	2	2094.0237	1.23	0.3021
	Residual	45	38321.2888	no test	no test
Red Clover	Regression	2	668.4598	1.45	0.2462
	Residual	45	10400.7433	no test	no test
Orchard Grass	Regression	2	16.6440	0.26	0.7685
	Residual	45	1413.8352	no test	no test
DFWT grasses	Regression	2	6968.8059	2.71	0.0773
	Residual	45	57816.4388	no test	no test
Weeds	Regression	2	3962.0470	1.37	0.2635
	Residual	45	64874.9321	no test	no test

A.N.O.V.A table for Table 6.2.4.B Within Field Variance and Between Field Variance of Percent Cover by Cohort and Sampling Year.

Sampling Year	Cohort	Species	Source of Variation	DF	SS	F-value	p-value
1998	1996	Seeded	Cohort	3	19334.9646	10.19	0.0001
			Error	36	22763.2292		
		Weeds	Cohort	3	19824.8333	19.41	0.0001
			Error	36	12257.6667		
1998	1997	Seeded	Cohort	5	21708.7257	7.30	0.0001
			Error	66	39248.8542		
		Weeds	Cohort	5	1557.5729	2.49	0.0395
			Error	66	8244.1458		
1998	1998	Seeded	Cohort	5	27912.8924	9.35	0.001
			Error	66	39421.7708		
		Weeds	Cohort	5	405.1944	3.22	0.0115
			Error	66	1658.6250		
1999	1997	Seeded	Cohort	2	2888.7639	4.45	0.0195
			Error	33	10703.4792		
		Weeds	Cohort	2	1208.6806	4.62	0.0171
			Error	33	4320.7292		
1999	1998	Seeded	Cohort	5	7762.4583	1.86	0.1130
			Error	66	55036.5417		
		Weeds	Cohort	5	9666.4757	5.81	0.0002
			Error	66	21954.9375		
1999	1999	Seeded	Cohort	3	23821.9739	22.15	0.0001
			Error	44	15772.2708		
		Weeds	Cohort	3	6377.4323	45.34	0.0001
			Error	44	2063.0208		

DF for cohort = number of fields – 1.
DF for error = number of fields (number of observations/field – 1)

APPENDIX 2 – List of Plant Species Found on the Set-asides.

Botanical Composition of Weed Species Found on Set-asides.

BROAD LEAVED SPECIES AND RUSHES

Scientific Name	Common Name
Amaranthus retroflexus	red root pigweed
Brassica spp.	mustard weeds
Capsella bursa-pastoris	shepherd's-purse
**Chenopodium album*	lamb's quarter
Cirsium arvense	Canada thistle
Cirsium vulgare	bull thistle
Convulvulus arvensis	field bindweed
**Epilobium spp.*	willow herb
Equisetum arvense	horse tail
**Gnaphalium spp.*	cudweed
Holcus lanatus	velvet grass
**Juncus bufonius*	toad rush
Lythrum salicaria	purple loostrife
Matricaria maritima	scentless chamomile
**Matricaria matricariodes*	pineapple weed
Plantago major	broad leaved plantain
P. lanceolata	narrow leaved plantain
**Polygonum persicaria*	smartweed
Rumex acetosella	sheep sorrel
R. crispus	curled dock
Senecio vulgaris	common groundsel
Solanum spp.	nightshade
Sonchus spp.	sowthistle
Spergula arevensis	cornspurry
**Spergularia canadensis*	sand spurry
Stellaria media	chickweed
Trifolium hybridum	alsike clover
T. pratense	red clover
Typha spp.	bulrush

*** indicates weeds found in anomalous areas in 1999.**

Botanical Composition of Weed Species Found on Set-asides (continued).

GRASSES	
Scientific Name	**Common Name**
Agropyron repens	cooch/quack grass
**Agrostis spp.*	bentgrass
**Alopecurus geniculatus*	marsh foxtail
**Echinochloa crus-galli*	barnyard grass
**Lolium spp.*	annual or perennial ryegrass
Phalaris canariensis	reed canary grass
**Poa spp.*	bluegrasses

*** indicates weeds found in anomalous areas in 1999.**