GOOSE FORAGING IN ARCTIC HABITATS WITH A PROTOCOL FOR A RAPID GROUND BASED ASSESSMENT OF ITS IMPACTS ON NORTHERN PLANT COMMUNITIES

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Goose foraging and its impacts on northern plant communities: developing a rapid assessment protocol

Introduction

Over the past four decades, the increase in populations of geese around the world, often considered to be driven and supported by changes in availability of agricultural crop foods on wintering and migration areas, has focused attention on goose herbivory in temperate, sub-arctic and arctic habitats. Lesser and greater snow geese and Ross's geese are the North American species that have attracted most attention, because of their rates of increase and overall population sizes, and because they employ foraging methods that can be damaging to plant communities when concentrated in time and space. Canada geese have also greatly increased owing to a combination of factors, including occupying suitable agricultural landscapes and using agricultural by-products. Canada geese also use destructive foraging methods, but much less so than snow geese. Cackling geese and greater white-fronted geese populations in North American have also benefitted from winter and migration habitat changes. The degree to which each of them may use damaging foraging methods in the arctic and subarctic is unquantified. Brant and emperor geese, which migrate and winter largely in natural habitats, have not taken advantage of high energy terrestrial foods. All of the species are terrestrial grazers when the season and situation presents itself, which is the case in subarctic and arctic wetlands for the majority of the snow-free period. These species can co-occur in various mixtures throughout the year and all are confronted with changing availability and condition of habitats, regardless whether they are the causative agent. In the case of the arctic and subarctic regions, habitats used by geese are not ubiquitous nor uniformly available in time or space, and are often of high value for other migratory wildlife. Thus, the assessment of impacts of goose herbivory on plant communities is of material interest to the management and well-being of the ecosystems and habitats and all their component species.

The Arctic Goose Joint Venture has recognized the significance of the goose herbivory issue in its Strategic Plans over the past 20 years (most recently AGJV 2008). It has fostered acquisition of knowledge through support of research programs throughout the

North American arctic and subarctic, special publications, and working groups. In 2013, the AGJV identified priority research and information issues and gaps related to the high populations of snow and Ross's geese. Among the highest ranked gaps was the relative lack of information on the condition of arctic staging areas and breeding colonies. More specifically, it was recognized that there is a paucity of information on the status of habitats at the largest eastern arctic colonies (e.g., Baffin Island and Southampton Island) relative to the central arctic (Queen Maud Gulf), the subarctic (e.g., La Pérouse Bay, Akimiski Island) , the eastern high arctic (Bylot Island), and Alaska (e.g., the Yukon-Kuskokwim Delta). Additionally, there is little information on habitat conditions at some new colonies (e.g. Prince Charles Island, Air Force Island, Coats Island) and staging areas outside the subarctic and beyond coastal areas are virtually unknown. The remoteness, low human population, limited infrastructure, great distances and large expense of working in the arctic have combined to hinder information collection except at a few long term research and monitoring sites.

To overcome current deficiencies in knowledge, it was determined that two approaches could and should be used to determine habitat conditions in relation to goose abundance and distribution. The first is the use of remote sensing. Change detection using Normalized Deviation Vegetation Index has been taken at several colonies and staging areas (Jano et al. 1998, Jefferies et al. 2006). Land cover classification of goose breeding areas has been undertaken by Didiuk and Ferguson (2005), Fontaine and Mallory (2011), and it has also been applied at West Hudson Bay and Baffin Island (Didiuk, *in progress*). Comparison of land cover proportions over medium term intervals (e.g., 10 years) can be used to assess the relatively active change caused by goose populations. The advantage of this method is that it allows for the use of information from readily available satellite images to create land cover classifications; it requires an initial ground level assessment to verify the classifications, and then allows for change detection without ground assessment (e.g. Mallory, *in progress*). It can help identify areas and extent of affected habitats and extend results from ground truthed areas to remote areas, but without ground evaluation it cannot necessarily identify the cause or the intensity the damage. The second approach is the use of ground level methods for fine scale assessment of the causes and intensity of impacts. Although not all change processes are goose induced (e.g. caribou can reduce standing crop, isostatic rebound can lead to change in exposed sediments in intertidal areas), the types of damage caused by geese are clearly identifiable at certain times of the year (e.g., grubbing in spring, shoot-pulling in spring, grazing in summer).

At areas where no previous evidence of a link between geese and habitat change has been established, ground level assessment is preferred. However, at a scale necessary to establish the extent of goose related habitat impacts, it will necessarily be expensive because of the need to access remote and undeveloped areas of the subarctic and arctic. Dedicated evaluations studies will also be time-consuming. To facilitate collection of larger amounts or information more quickly, the AGJV determined that a simple rapid assessment protocol would be valuable, especially one focused on methods readily deployed by staff with a minimum of plant ecology training, but who will be in the habitats of interest for other purposes (e.g. goose banding, shorebird surveys, other bird or mammal surveys, and geology surveys).

The goals of development of a rapid assessment protocol are to allow for efficient assessment of the condition of habitats and the likelihood of assignment of impacts to goose herbivory based on ground level techniques. It is meant to be used at any site, either as a single assessment or repeated over time at intervals (e.g. over 5 or 10 year periods) to allow for change assessment and trends, including documentation of revegetation following severe herbivory events. It is also primarily meant to be applied during late summer (i.e., late July and early August) near peak of growing season, when goose banding and other survey activities requiring helicopters are most likely to occur. However, where research camps are occupied throughout the snow free season, the methods are expandable and some are designed for earlier season (e.g., shoot pulling assessment) or for season-long monitoring (e.g., exclosures). There are a variety of plant ecology methods that can be used to assess herbivory (e.g., Moore and Chapman 1986, Molau and Mølgaard 1996) and many have been used in goose research and monitoring studies (Jefferies et al. 2003, Jefferies et al 2008, Gauthier et al. 2004, Alisauskas et al. 2006, Slattery and Alisauskas 2007, Person et al. 1998). The rapid assessment protocol is built on these foundations and provides a primary tool kit of methods for surveys. Studies of increasing complexity, where time and resources are available for more labour-intensive and time-consuming approaches, can also use the protocol and the other methods describe in this report, but should also refer to the references above.

This report first provides a brief review of the foraging habitats, of foraging habits of geese in spring and summer, of the methods and procedures to determine the use of an area by geese, and an overview of the methods and procedures to determine the condition of plant communities. The latter portion outlines the recommended protocol.

Goose Habitats

Geese use a variety of subarctic and arctic habitats during spring staging, nesting, brood rearing and fall staging. Monitoring methods are not equally applicable in all of these habits. This section is intended as a summary of the habitats likely to be encountered in the subarctic and arctic goose areas, including salt marsh (intertidal and supratidal), brackish marsh and lagoons, freshwater marsh (including dry, mesic and wet sedge fen), lake and pond shorelines, stream (riparian) edges, moss, lichen, upland (esker, ridge, terrace), foothills, and isolated ponds).

Salt marsh

Intertidal and supratidal salt marshes are among the most productive ecosystems. In the subarctic and arctic, they cover low lying areas from the first colonizing plants to that gain a foothold in the lowest elevations

Brackish marsh and lagoons

In some parts of the arctic, low-lying coastal areas are periodically flooded but otherwise fed by precipitation and seasonal freshwater run-off. These areas are brackish and host plants less salt tolerant that salt marsh, but are similar to salt marshes in many respects (e.g. land form).

Freshwater marsh and fen

Above the zone of ocean tidal action, and covering the greatest area of lowlands in the subarctic and arctic, these freshwater wet meadows are a mosaic of many different types of plant communities, driven by variations in substrate and moisture content. In areas with less drainage, sedges and grasses dominate.

Lake and pond shorelines

A subcategory of the freshwater marsh, shorelines of permanent lakes and large ponds offer special features for geese, particularly loafing spots in proximity to escape habitat for moulting birds. Food plants such as aquatic sedges and grasses are often concentrated along shorelines.

Stream edges

In some locations, riparian areas along streams are a major foraging habitat.

Upland

Although used to a lesser extent, uplands that contain perched ponds and lakes, and uplands that have moss-lichen-ericaceous shrub cover contain some extent of graminoids and berry producing plants used by geese.

Geese and Their Foraging Methods

Overview

Although species of geese share many foraging methods, the degree to which each species relies or uses each type differs, which allows habitat and resource partitioning at multiple scales. Glazener (1946) classed geese into “grazers” and “grubbers”. All geese are grazers at some point in the annual cycle, especially when feeding on native vegetation and on the northern breeding grounds in the post-hatch period when goslings are small (Owen 1980). Adaptations of body size, bill structure and physiology of some species allow some specialization on different plant parts, forms or species at certain times of the year (Bolen and Rylander 1978, Ogilvie 1978, Owen 1980). The following summary of foraging methods and effects in the subarctic and arctic is based on observations of snow geese and Canada geese on the Hudson Bay and James Bay coast (cf. Jefferies and Abraham 1984) supplemented with literature to reflect a broader interest in other arctic goose species and to include new information where available.

Snow Geese (both Greater and Lesser) have head skeletal and musculature adaptations that permit efficient extraction of belowground plant parts such as roots, rhizomes, bulbs and tubers. Mandibular lamellae have been modified to a tooth-like edge for excavating in soil, for gripping and tearing coarse plant tissues, in combination with a steep head profile and neck musculature. This is particularly useful in temperate salt marshes where large plant forms predominate (e.g., *Scirpus* spp., *Spartina* spp.). Historically, the winter diets of greater and lesser snow geese were dominated by these robust species on the Atlantic coast and Gulf Coast. They share some of these morphological traits with Greylag Geese (Owen 1980) which also make use of similar plants in temperate marshes in Eurasia (Esselink et al. 1998) (e.g., *Phragmites* spp.) and with White-fronted Geese (Bolen and Rylander 1978). In the subarctic and arctic, grubbing allows snow geese to obtain difficult to access below ground resources where plant nutrients are stored, which other geese have less success in exploiting (Prevett et al. 1985, Ganter and Cooke 1996). At other times, snow geese are grazers or pullers.

Ross's Geese resemble white morph snow geese but are smaller bodied and also differ in body proportion (Alisauskas 2001), with smaller bills relative to head size. They lack the reinforce mandibular lamellae of greater and lesser snow geese. The shorter, lighter bill may be less effective for grubbing for food. Because they often/usually occur in large mixed flocks with lesser snow geese during spring migration and pre-breeding, thus the extent to which they employ this method is unknown. However, they do grub in spring when foraging for sedges and grass roots and they uproot tufts of mosses during nest building (Didiuk et al. 2001). They also grub during incubation (Gloutney et al 2001). The smaller stature of the Ross's Goose and its smaller bill may allow grazing of shorter graminoid vegetation that the related snow goose. Ross's geese appear to be grazers for most of the annual cycle, although some grubbing may occur after fledging and before fall migration (Didiuk et al. 2001).

White-fronted Geese have robust bill structures that resemble those of snow geese (Bolen and Rylander 1978), an adaptation to winter feeding on rhizomes of marsh plants such as bulrush (Ogilvie 1978). In North America, during spring migration, white-fronted geese are known to forage on the flowering heads of *Equisetum* (Gill 1975) in boreal areas. Upon arrival to their arctic breeding grounds, they feed significantly on the tillers of *Puccinellia* spp. before and during snow melt, along with other grasses, and increasingly feed on small stature *Carex* spp. and *Dupontia fisheri* as melt proceeds and after snow melt; they can also grub extensively (e.g., 58% of time) before widespread snow melt (Carrière et al. 1999).

Canada Geese are chiefly grazers in spring and summer, but breeding birds of some races (e.g. *B. c. interior*) regularly grub small patches. This is observed on Akimiski Island, mostly involving males on territories during the incubation period (Gleason 2003). Large subspecies are also known to grub some saturated grass habitats in winter (KFA, pers. obs., P. Castelli, pers. comm). Cumulative grubbing of patches can lead to bare sediments.

Cackling geese are predominantly grazers and like Ross's geese, their small stature and bill structure may allow them to be more efficient grazing shorter species and forms. Some forms (e.g., *B. hutchinsii*) do grub in spring on the arctic breeding grounds, but to a lesser extent than white-fronted geese (Carrière et al. 1999) and lesser snow geese (KFA, pers. obs.).

Brant are predominantly grazers and like Ross's geese and cackling geese, their small stature and bill structure may allow them to be more efficient grazing shorter species and plant forms. During winter and migration they are the most aquatic foragers among North American geese, feeding on eelgrass and algae. Owen (1980) states that they grub for rhizomes in sand.

Emperor Geese. Like brant, emperors are primarily grazers and more aquatic and marine feeders than other geese, but apparently without special foraging adaptations. They grub for rhizomes and overwintering bulbs and roots and shoots (Petersen et al. 2011).

Spring foraging

During spring, pre-breeding geese are in a hyperphagic state (Krapu and Reinecke 1992). Both genders require reserves of protein and lipid for the nesting process, females for egg-laying as well as the energetic demands of incubation, and males for defence of females, nests, territories and feeding space. They seek the best available sources of nutrients in whichever environment they find themselves. Forage availability in the arctic at this time of year is largely driven by abiotic and physical factors, such as weather, snow cover, ice cover, and water depth.

Grubbing. This term refers to "tearing out of tubers, rhizomes and other underground parts of plants growing in wet marsh land" (Glazener 1946). In the arctic spring, this is especially focused on graminoids (grasses and sedges). It is a destructive foraging process which can initiate a process of change in ground conditions that often ends in bare sediments (Srivastava and Jefferies 1995, 1996). Illustrations of grubbing as described in the following text are found at the end of the document (Figures 1-9).

1. Geese often arrive on the subarctic staging and breeding grounds when only small patches of vegetation are exposed from snow (e.g., Carriere et al. 1999, Hupp et al. 2001). At this stage, there is no above-ground growth of vegetation and the soil surface may be still frozen in most places. Considerable feeding occurs at this stage of the season, but it varies among goose species and with latitude, dependent on local conditions. The primary objective of grubbing is the acquisition and consumption of the below ground part which contain carbohydrates and fatty acids, but protein is also available.

2. Grubbing is dependent on the thawing of the upper layers of sediment for at least a few hours per day. The fine roots are accessible when a few centimeters of soil surface are thawed. This frequently occurs when melt water collects in vernal pools, and where an intertidal or supratidal area of graminoid turf is inundated with (relatively) warm melt water, or where exposed vegetation receives

sufficient radiation to thaw the underlying soil. In other words, grubbing is restricted to sites where the layer of vegetation and plant litter is thin and where there can be sufficient heat exchange to melt sediments. Unconsumed leaves and roots form a suspended mass where standing water occurs or a blanket on the moist surface where no standing water occurs.

3. In southern Hudson Bay and James Bay, grubbing occurs in short graminoid swards of the grasses *Puccinellia phyrganodes* and *Festuca rubra* and the sedge *Carex subspathacea* in the upper levels of salt marshes and in low lying relict areas of salt marsh which are inland beyond the uppermost limit of spring tides. *P. phryganodes* and *C. subspathacea* communities with *C. ursina* and other small sedges also occur as coastal turf in the northern Hudson Bay, Foxe Basin and Queen Maud Gulf areas where geese breed, and are similarly grubbed. Other plant communities farther north with similar characteristics include the grasses *Dupontia fisheri* and *Alopecurus alpinus*. *D. fisheri* is common in wet meadows on alluvial soils, such as in estuaries and on brackish lagoon shores which may be flooded by occasional high tides. *A. alpinus* is common and widespread in wet tundra, especially by brooks and lake shores in coastal sites. In addition, bulbils of *Triglochin maritima* (sea arrow grass) are torn out of the ground by geese in spring.

4. Another type of habitat where grubbing occurs is on well drained sites where there is a short turf (like a golf course) of grasses, sedges, mosses and herbs. Such sites include the tops of low lying dune systems, low, flat-topped gravel ridges and low rises in coastal areas.

5. The type of grubbing depends on the goose species, the plant cover, and the terrain. Grubbing by Canada geese is usually restricted to either well drained sites or else sites in the upper levels of salt marshes. The geese tear out small plugs of turf from the swards exposing underlying sediments. This action is directed from above the sward and small plugs are left scattered about the surface, looking similar to aeration plugs on treated lawns. Grubbing by the Canada geese is very patchy and unsystematic, large sections of turf are rarely removed and they are less reliant on roots of plants than are snow geese (Prevett et al. 1985).

6. Grubbing by lesser snow geese is different from that carried out by Canada geese. Usually, it is much more systematic and thorough in all types of habitat; most of the vegetation is eaten. A goose grubbing continuously will removed 1 m^2 per hour of short turf, exposing the underlying sediments. A few shoots (tillers) remain in the disturbed sediment. The birds will return to a site in subsequent years and grub at the edge of a previously cleared patch, so that it is enlarged over successive years.. This results in the terracing of land surfaces where they slope, such as around the edges of ponds, and lakes or the banks of streams.

7. Besides this "phalanx" type of grubbing where the birds grub on a broad front, there is also a "guerilla" form of grubbing which is characteristically found in

well drained sites or at sites which have become re-vegetated following grubbing. This type of grubbing is less systematic in direction and superficially resembles in appearance termite or woodworm damage to wood. Finally, there is the removal of individual plants which leaves individual beak holes (Ganter and Cooke 1996).

8. Once the growth of above-ground vegetation commences in spring, grubbing essentially ceases. Further grubbing may occur in late summer or early autumn when the vegetation is senescing and reserves are being transported to leaf bases or to below-ground tissues.

9. There are physical processes occurring on shorelines such as ice rafting and ice shear that may superficially resemble the effects of grubbing, particularly by mid-summer when fine-scale erosion of exposed sediments and oxidation of iron compounds are well advanced. Detection of spring grubbing in summer is, therefore, difficult in areas where ice action is prevalent. In intertidal habitats most ice action is limited to the lower levels of marshes. In early spring low-lying, areas adjacent to shallow drainage channels may be encased in ice and hence protected from the effects of grubbing. In contrast, slightly elevated areas between drainage channels are exposed and grubbed. This results in intact swards adjacent to drainage channels and bare sediments on elevated areas.

10. Re-growth of vegetation at grubbed sites is closely correlated with the size of the cleared patch, the type of underlying sediment and the moisture regime of the sediment Although much of the grubbing by lesser snow geese is thorough and systematic, a few shoots of grasses, sedges and herbs remain. These are the nucleus for the reestablishment of the vegetation in grubbed patches. Over a period the vegetation re-establishes, only to be grubbed again. Types of habitat listed in and above are often a complex vegetational mosaic of patches 1-5 m in diameter reflecting the time that has elapsed since each patch was grubbed. The standing crop (biomass) and the species composition differ between patches. Field biologists visiting sites used by lesser snow geese over successive years should look for these mosaics in what otherwise appears to be a uniform habitat, as evidence of past grubbing events.

11. Where patches are above approximately 1.5 m in diameter, particularly where the underlying sediment is saline, re-growth of vegetation following grubbing may fail to occur. This is the result of increased rates of evaporation of soil water when the insulating layer of live and dead plant material has been removed. The upper layers of soil dry out and become hypersaline and salt-marshes plants are intolerant of these conditions. Some plots have remained several years without vegetation (Hudson Bay Project data). *Salix* spp. and other shrubs often die when the sediments become hypersaline (Iacobelli and Jefferies 1991).

12. Plant communities protected by extensive snow or ice cover or where there is a thick insulating layer of plant litter and where the height of the vegetation is above approximately 15 cm can escape grubbing (e.g. shallow ponds containing

bulrushes (*Scirpus* spp.) and spikerushes (*Eleocharis* spp.)(Prevett et al. 1985). These three characteristics are closely interrelated and preclude early thaw of the upper layers of soil where the roots and rhizomes are located. Communities of *Carex aquatilis* and related species in sedge meadows are characteristically not grubbed for the above reasons. Often lower elevation plant communities on stream and pond edges are not grubbed while communities on higher elevations of the same slope suffer damage.

Shoot-pulling in freshwater wetland with organic substrate. This refers to the cutting of individual shoots of large sedges, a specialized form of grazing (Owen 1980). Geese eat the white, basal portion of shoots that is rich in soluble carbohydrates and nitrogen compounds and discard the remainder of the shoot, including the tips which may be avoided because of phenolic and other secondary chemical compounds present at this early stage of development (Jefferies and Edwards 2008). Roots and rhizomes of these plants are rarely removed during shoot pulling, but may be uprooted incidentally where this activity occurs in very soft sediment situations. While not as immediately destructive of a plant sward as grubbing, because the substrate usually remains intact, intensive and sustained shoot-pulling can lead to death of the clones of graminoids and creation of an alternate vegetation state, namely moss carpets, with an eventual endpoint in exposed peat. Images of shoot-pulling as described in the following text are shown at the end of the document (Figures 12-15).

1. This foraging activity is carried out primarily by adult geese (including yearlings) in spring before nest initiation and egg laying. It has been also observed in late summer (August) when both adults and then fully fledged goslings may be involved.

2. Shoot-pulling is particularly prevalent in mires (fens) rich in different sedge species once there is standing melt water and staging geese wait and feed on the. different sedge species, particularly *Carex aquatilis and C. aquatilis* (*stans*). However, this removal of shoots by the geese can occur in oligotrophic, mesotrophic and eutrophic plant communities. Other sedges (e.g. cotton grasses, *Eriophorum* spp.) receive the same treatment. A typical wet sedge meadow where this type of feeding occurs is illustrated in Didiuk and Ferguson (2005) on page 22.

3. Evidence of shoot pulling may be difficult to discern, depending on the timing of field visits. Large windrows of discarded sedge shoots with tips intact and bases torn are evidence of shoot pulling earlier in a season. Falling water levels over the summer result in these shoots being strewn amongst other vegetation. At some northern locations, in late years when non-breeding is prevalent, visits as late as early August yield amply evidence of shoot pulling, e.g. Baffin Island in August 1999, a year of widespread breeding failure (KFA, pers. obs.).

4. At some localities where the local hydrology is suitable, depletion of sedge shoots over successive years has led to the development of moss carpets. They are

particularly well developed around lagoons, ponds and on the edges of brooks where water is flowing into these drainage systems. Some of these moss carpets maybe over 100 m in length and over 50 m wide. The carpets can grade abruptly into dry willow heath tundra vegetation.

5. The moss carpets may be colonized by *Potentilla palustris* (marsh cinquefoil) and horizontal shoot systems of nearby willows may spread across the surface of the carpets. This is particularly prevalent around larger permanent lakes and on margins of some depositional areas such as low vegetated sedimentary islands in rivers. The geese do not forage intensively on any of these species.

Vernal pools

1. These are shallow, transient pools that are fed by melt water. They occur in low lying areas of various graminoid communities, including *Dupontia-Alopecuris* meadows, *Festuca rubra-Calamagrostis deschampsioides* meadows and in *Puccinellia phryganodes-Carex subspathacea* communities in intertidal/supratidal marshes and inland relict salt marshes.

2. In spring the water temperature in these vernal pools is 10^{o} to 15°C above the ambient air temperature on fine sunny days. The high water temperatures (ca. 15°C) promote the above-ground growth of these graminoid plants The verdant growth compared with the brown appearance of adjacent vegetation attracts geese which graze intensively on the green leaves and shoots.

3. As the geese defecate on average once every four minutes, faecal matter rapidly accumulates in these pools. The nutrient enrichment of the water by faeces and the high water temperatures promote rapid algal growth and a green scum of filamentous algae spreads across the ponds.

4. In late spring as the water level recedes the green algal scum is deposited on the graminoid plants where it dies and decays. The dead algal mat and the decomposition products kill the underlying graminoid vegetation and bare patches of sediment are present by mid-summer which dry out. Wind removes dead algal and plant litter.

5. In some cases, the warm, saturated surface soils in these vernal pools provide a point of onset for goose grubbing and the processes described above can be initiated. This happens, e.g., on Akimiski Island in *Festuca rubra* swards which would otherwise be too coarse/rank for foraging.

6. In brackish pools and moist soil sites, whole plants of the forb *Senecio congestus* are uprooted (Figure 10) . Early vegetative growth of *Senecio* plants of these species makes it particularly vulnerable to up-rooting which is confined to spring. Evidence of this type of foraging is the presence of floating leaves or partially consumed bases of the plants missing the roots. The white basal portions and the attached ring of fine roots is the target of the geese because of carbohydrate

concentrations (Jefferies and Edwards 2008); the tips are never or rarely eaten because of chemical compounds. As water levels decrease, the discarded green leaves and partially consumed parts can collect in wind-rows along the shorelines of ponds and vernal pools. These ponds are usually also highly turbid in the period for several hours after the foraging activity.

7. In some locations, *Hippuris* spp. are pulled up very early in the season (Reed et al. 1998) (Figure 11). Evidence is the presence of floating segments of rhizomes, sometimes wind-rowed along shorelines similar to *Senecio.*

Roost sites

1. In early spring birds roost at exposed sites free of snow and ice. Piles of dung from the birds kill the vegetation beneath the dung. The higher plants are replaced by mosses which colonize the soil surface. These mosses are characteristic of dry sites. In dry summers, however, the mosses die and are blown away, thus exposing the underlying sediments which are eroded by the wind. The removal of soil organic matter favours the growth of cyanobacterial (blue-green algal) mats in subsequent springs when conditions are wet. These dry out in summer, are blown away and the erosion cycle is perpetuated.

Summer foraging

Removal of inflorescences

1. In early summer a number of arctic herbivores, including lesser snow geese forage on the developing inflorescences. The following genera are particularly sought after: *Salix spp.* (willow), *Oxytropis* (locoweed), *Plantago* (plantain), *Pedicularis* (lousewort), *Equisetum* (horsetail) and *Polygonum* (knotweed).

Grazing of short graminoid vegetation

2. Intensive grazing of short graminoid swards occurs immediately after hatch where available, often as grazing lawns (golf-course like turf) in intertidal areas, grazing can continue throughout the summer until goslings are fledged and the birds migrate southwards (e.g., Sedinger and Raveling 1984, Cargill and Jefferies 1984).

3. The major types of short graminoid communities in which intensive grazing by geese has been observed in the post-hatch period are lawn like turfs of intertidal or supratidal *Puccinellia phryganodes-Carex subspathacea* swards, *Carex subspathacea-Carex ramenskii* swards, *Festuca rubra-Calamagrostis deschampsioides* swards and brackish *Dupontia fisheri-Poa arctica-Alopecurus alpinus* communities. Impacts of grazing and prevention of grazing is shown in Figure 16.

4. Where available, foraging by adults and goslings is particularly intensive in these intertidal and supratidal plant communities in the first 3-4 weeks after hatch when the goslings are small and their guts are not fully developed. Results from feeding trials indicate that when goslings are at this age, few plants fulfil their nutritional and energetic demands within the constraints of their physiology.

5. Areas of extensive freshwater marshes, such as inland nesting areas at Queen Maud Gulf, Banks Island and more inland areas of southern Hudson Bay also contain species of short stature plants that fulfil the same purpose for young goslings, including *Triglochin palustris* and *Equisetum variegatum* (Jefferies and Edwards 2008, Winiarski et al. 2012).

Grazing of tall graminoid vegetation

1. In southern Hudson Bay, as local areas of high density, high productivity short-turf vegetation have deteriorated, or were destroyed, family groups of geese switched to using alternative, presumably less preferred sources of forage. These include inland sedges and grasses in fresh-water or brackish meadows. In the low arctic (e.g. northern Hudson Bay, Queen Maud Gulf) and the high arctic (e.g., Bylot Island, Banks Island), grazing of taller graminoid vegetation is the norm (preferred) forage for snow geese. These areas provide ample nutrition for adults and goslings.

2. Species which are eaten vary depending on location, but include *Carex aquatilis*/*Carex stans*, *Eriophorum angustifolium*, *E. scheuchzeri*, *Calamagrostis canadensis*. The tops of the leaf blades are eaten as the meristematic tissue in a growing state has the highest soluble nitrogen content available in the plant's tissue.

3. In southern Hudson Bay, the feeding on the above species occurs from mid-season onwards when the goslings are 25 days or older because at this stage of growth goslings are tall enough to reach these shoots and additionally their gut has developed sufficiently to allow them to digest the plant material.

Grazing of tussock graminoid tundra

1. Lesser snow geese and Ross's geese nesting in high densities in tussock graminoid tundra can reduce such areas to expose peats by intensive and sustained grazing. The geese shred individual tussocks of *Eriophorum vaginatum* and used it for nest building.

Methods of vegetation monitoring: what to measure?

The major effect of goose herbivory in the area of interest is to alter the trajectory of plant community succession. In sustainable situations (i.e., when herbivore numbers are below a threshold), herbivory can maintain communities in an early successional stage lead to a grazing lawn where selected species are favoured severe cases, this leads to an alternate state (e.g., Cargill and Jefferies 1984). This section provides a general review of available methods for measurement of plant communities in preparation for selecting a minimum set or standard set of rapid assessment measures for cross-site comparison and an enlarge set of measures that may be employed where time and resources allow for more detailed site assessment (i.e., where a season long camp is established for study or geese or other species inhabiting the same habitats, such as shorebirds and passerines). This material is drawn from texts (Moore and Chapman 2003) and protocols developed for long-term arctic plant and herbivory research and monitoring programs (Jefferies and Abraham 1994; Molau and Mølgaard 1996; Gauthier et al. 2004, Jefferies et al. 2008).

Overview of Measures of Plant Species and Community Condition

Ground cover

The proportion of ground covered of broad type-categories (e.g., vegetation, bare ground, water, rock, hummock, tussock, moss understory) yields a general state of the landscape at a meso-scale and can be used to classify a site to wetland type. Best information comes from identification of vegetation at species/genus level but functional groups (e.g., grasses, sedges, graminoids (monocots), forbs (dicots), shrubs, moss, lichen) can be substituted where botanical expertise isn't present. Other categories of information can be recorded with minimal additional effort. Simple step-point transects are the easiest method.

Species composition

Plant species composition (e.g., percent cover, frequency of occurrence) yields more exact information about the site. Again, at the species/genus level this requires some botanical expertise and at least a basic training in identifying plants to functional groups. Composition data are most often obtained using small quadrats.

Standing Crop

Annual production, or live standing crop, measured as live phytomass per unit area, can be used as a simple index to grazing history (in combination with other general information from the site). It is usually measured with small turf samples or small quadrats and is a destructive sampling method. Standing crop in short-graminoid turfs can be assessed visually as categories (e.g. sparse, patchy, moderately dense, dense) and compared to biomass estimates with a reference photograph.

Net primary production is a preferable (to standing crop) measure of ecosystem condition but its measurement is labour and resource intensive and is most suited to situations where a seasonal camp is established with access to a field lab. Jefferies et al. (2008) provide detailed instruction and equipment requirements for NPP measurement in a variety of tundra plant communities.

Height of vegetation

Vegetation height can be used as an index to both production and to cumulative grazing pressure with other general information from the site. It can be measured at points along transects or in quadrats. Average maximum height is easier to measure than average overall height.

Flowering heads

The proportion of flowering heads can be used as an index to plant phenology. It can be measured at points along transects or in quadrats. Recording of both number of flowering and non-flowering shoots/plants of the dominant/target forage species is required. Grazing pressure and sometimes timing of grazing related to phenology can also be captured.

Moss

Moss responses are indicative of nutrient inputs from geese as well as environmental characteristics. Presence/absence of moss, condition of moss (live/dead) and moss thickness may be useful indices.

Lichen

Presence or absence of lichens can be an index of cumulative trampling by herbivores, or in some cases cumulative consumption (e.g. by caribou).

Measures of Goose Foraging Activity

Ground cover (areal extent)

The cumulative impact of grubbing and grazing can be detected in the mosaic of communities present at a site. As for general land cover, this is best accomplished by use of transects that sample an area representatively, or in some cases systematically and is easy to integrate with general land cover typing. Whenever near coast, the transects should be anchored at the vegetation edge, which will yield vegetation zone information (width of intertidal, position of supratidal/brackish and freshwater zones). In inland wetlands, four 100m transects at random points can be established in typical vegetation. Percent cover of vegetation, bare substrate, and water should be recorded, along with general evidence of grubbing, shoot-pulling, grazing, shrub condition.

Grazing activity

The proportion of grazed stems in a sward can be an index of grazing pressure. It can be measured in quadrats randomly place along transects or at random points. Number of both grazed and ungrazed shoots/plants of the dominant/target species is required. Additionally, where short graminoid turfs are collected for standing crop measurements, the proportion of grazed stems can be visually estimated by percentage categories. In tall graminoid vegetation, where standing crop may not be measured with turf samples, the number of grazed and ungrazed shoots of the dominant species can be measured in place in a small quadrat.

Grubbing activity

Presence of grubbing activity is used as an indicator of geese foraging in spring, as it mostly occurs at or near the time of snow melt and surface thaw and before plants “green up” above ground. Simple presence can be recorded, but it is better to measure occurrence along a transect and if possible, add recency of grubbing (i.e., current year or older); this takes some experience but field categorization used in combination with close-up photographs for later interpretation is easily accomplished.

Shoot pulling activity

Like grubbing, presence of shoot-pulling activity is an indicator of goose use in spring. If the activity is recent (e.g., late season shoot-pulling by non-breeding geese or fledged families), the total number of shoots and the total number of pulled shoots can be recorded. Spring shoot pulling activity is difficult to reliably determine by late July and early August because of drying and decomposition, but it is sometimes possible to determine its occurrence (if not proportions of stems). When activity is recent, counts are made in small quadrats placed randomly or systematically along transects and close-up vertical photographs of quadrats can be used for post-hoc analysis.

Faecal droppings

Faeces can be used as an index to intensity of use of a site. Faecal counts integrate the number of geese with the relative amount of time spent in the site. Counts within quadrats are the simplest measure. Additional information can be obtained from samples of fresh dropping for fragment analysis or bar coding for species determination, however these require freezing for later analysis.

Secondary effects

Cumulative damage to habitats result in impacts less directly than the foregoing methods listed above. These signs can also provide information on the nature, timing and extent of goose foraging. One example is increased salinity in areas of lower biomass and bare sediment patches later in the season after freshwater from spring melt evaporates. Testing soil salinities across habitats can indicate areas of goose damage (Srivastava and Jefferies 1995, 1996). Small soil samples can be collected for this purpose

Soil compaction is another example resulting from a combination of trampling, loss of aerating roots of vegetation and loss of soil water.

A third example is the presence of dead willow. Willows can be killed by hypersaline conditions that result from the stripping of insulating and filtering vegetation from around their bases (Iacobelli and Jefferies 1991). Recording presence of dead willows, and sampling soil beneath the willows for salinity analyses should be considered. Finally, the presence of dry, tough algal crusts on soil sediments reduces leaf growth and increase leaf death in areas with low biomass (Srivastava and Jefferies 1996). Recording presence of these crusts along transects is an additional measure.

Choosing Assessment Sites

Establishing the extent of occurrence of goose damage to plant assemblages or associations on a landscape can contribute to a general statement of the degree of intactness or cumulative impact of goose foraging over time. In arctic and subarctic habitats, these measures will differ among major wetland zones such as the immediate coastal zone and the inland zone, both because of landform and hydrology and because goose foraging methods and seasonal use differs between them. Proximity to known nesting areas of colonial geese also affects these measures. In the coastal zone, where grubbing is most likely to occur, the interest is in the area extent of vegetation and of exposed mineral substrates that may have resulted from grubbing. Within vegetated coastal areas, the occurrence of coastal turf communities (e.g., *Puccinellia phryganodes*, *Carex subspathacea*, *C. ursina*) and disturbance communities (e.g., *Senecio congestus*, *Salicornia* spp.) is of interest. These coastal turf communities grade into brackish and eventually freshwater communities as distance from the sea and elevation increase with the appearance of other short graminoid species (e.g. *Dupontia fisheri*, *Poa* spp.). In the inland zone, where grubbing is likely to be less extensive or even non-existent, but shoot pulling is likely to occur, the interest is in the area extent of assemblages, stand structure and presence of exposed peats. For individual assessment sites, stratification of habitats should be established using remote sensing of large areas (e.g., at the scale of a breeding colony (e.g. Boas River) or whole regions such as Southampton Island, West Hudson Bay, or West Baffin Island plains) and targets for number of sites for adequately precise local scale assessment need to be established. Didiuk (pers. comm.) recommends considering the coastal graminoid turf communities as the first sampling zone, the inland graminoid-dominated or moss-dominated freshwater wetlands immediately inland and adjacent to these as the second sampling zone, and patterned wetlands further inland as one or two additional sampling zone(s) depending on the remote sensing classification available for the region.

Protocol for Rapid Assessment

The following is the recommended protocol for late season rapid site assessments. It is primarily designed to be accomplished by one person while a crew is banding geese or undertaking other work. When available, 2-3 people can divide the tasks and accomplish the assessment more quickly allowing more sites to be completed and/or optional elements to be added. Total time needed per site for one person is approximately 1 hour per site (as this is likely to be within the time that a crew needs for banding). This can be shortened when needed. Mandatory elements are to be done first.

Mandatory elements are those listed below in recommended order of completion on site. This order is subject to adjustment depending observer experience, number of people helping and based on knowledge of how much time is available.

1. Site location (< 1 minute)
2. Site description (< 5 minutes)
3. Ground cover transect (integrating land cover type, vegetation height, grazing percentage, inflorescence percentage, condition of shrubs, and presence of grubbing/shoot pulling) (up to 40 minutes dependent on length of transect,)
4. Faecal counts (ca. 15 minutes)
5. Photographs (< 5 minutes)

Optional elements

1. 3-5 species composition quadrats integrating plant height, grazing frequency, and flowering stems (ca. 15-25 minutes)
2. Collect 3-5 standing crop samples (< 5 minutes)

3. Collect 3-5 soil samples for salinity testing (< 5 minutes)
4. Collect voucher specimens (vascular plants, mosses or faecal samples)

Equipment needed for Mandatory Elements

Waterproof field notebook (preferable for recording)
Digital recorder is an alternative to notebook recording, but contains risk of malfunction and noting that equivalent transcription time is required; not recommended)
Pencils
Digital camera
Hand counters (tally clickers) for faecal counts
Measuring tape (50m or 100m) for ground cover
Quadrat (25 cm x 25 cm, with sting or monofilament for cells) for composition
Ruler with mm units (50 cm transparent plastic) for plant height
Tent pegs (20)

Equipment needed for optional elements (notably for standing crop measurement)

Knives (wide bladed) or circular cutting tool (for standing crop)
Plant shears
Scissors
Filter papers (coffee filters will suffice)
Trays (ca. 20cm x 30cm x 5cm)
Forceps (assorted blunt tip and fine tip)
Envelopes (coin envelopes)
Indelible black fine tip marker and sharpie
Spikes/tent pegs (handy for marking locations during set up)
String

Mandatory Elements of the Rapid Assessment

Site location

All sampling locations (of transects, photos, sampling plots) should be recorded with hand held Global Positioning System units. Map datum should be standardized and noted (NAD 83).

Site description

An overview of the sampling site should be made at the outset (cf. Didiuk and Ferguson 2005, Johnston and Pepper 2009). At a minimum, the following should be recorded or scored:

1. general aspect (e.g., overall description of surrounding area, with dominant landform such as upland or lowland)

2. surficial expression (e.g. hummocks, tussocks, high center or low center polygons, ridges, etc.)
3. substrate (peat or mineral)
4. ground moisture (dry, mesic, wet, standing water)
5. estimate of water (percentage covered by water bodies)
6. dominant vegetation type (species and visual estimate of percent cover)
7. salt marsh or fresh water marsh

Ground Cover

The simplest method to capture the extent of land cover types at a local scale is a transect. In a coastal zone a transect should be established at the seaward end or salt march vegetation. The length of the transect is arbitrary and depends on the width of the zone, which varies considerable from site to site (the width itself is a useful measure best determined with these ground methods) but the aim should be to traverse the zone of turf communities, if time permits. A tape (50m or 100 m)can be laid out to as a guide (Kotanen and Abraham 2013), or a simple step-point transect method can be used (Abraham et al. 2005, Peterson et al. 2013). The dominant cover type within each step or 1-meter reach of tape is recorded. These types include plant species/genus if known or plant functional group if species is not known (grass, sedge, graminoid, forb, moss, lichen, shrub) plus non-vegetated cover types: bare sediment, water, rock.

At each tenth meter mark or step-point, the plant species/functional group and its maximum height should be recorded. If it is a forage species, record whether it is grazed or not and whether it has an inflorescence or not. If it is a shrub, record whether it is dead (100% of branches dead), in poor condition live (more than 1/3 of branches dead), or alive and healthy (< 1/3 of branches dead) (Peterson et al. 2013). The data yielded by this method will be counts which can be analysed as proportions and contribute to multiple objectives of the site assessment.

Faecal Counts

Faeces can be counted in 4 m x 4 m plots where there is continuous vegetation cover. These measurements are quick and it is possible for 3 to 5 plots to be done in each vegetation zone/community. The positions should be chosen at least 50 m apart within each zone. Mark the corners with stakes or tent pegs. Record only intact or nearly intact faeces and flick the faeces from the plot with a stick after each counting to avoid double counting. Hand counters (clickers) make the process less fallible to memory lapses. Faecal plots can be done by multiple people simultaneously to shorten time required.

Plot size can be reduced if droppings are high density. (During intense use of the salt-marsh flats at La Pérouse Bay, the densities of droppings per 4 m x 4 m area may exceed 600 per week).

Photographic record

Photos have many uses as reference and record of conditions, e.g. identification of habitat types and sometimes plant species, visual assessments of use (evidence of droppings, grubbing, shoot pulling, degree of grazing, etc) and comparisons with photos from earlier years at the same locations. Photographs of habitats, including oblique aerial photos, background, foreground and close-up views should be liberally taken within the time allowed.

A minimum set of 3 photographs should be taken within each vegetation zone encountered: 1) general horizontal view of wetland, 2) view at 45^o angle 3) vertical view of typical vegetation with a reference object (preferably a quadrat). Take a GPS waypoint at the beginning of each set and record the number in the notebook.

Optional Elements That Are Less Rapid

These methods can be implemented if and when time allows during a site visit for rapid assessment, or at seasonally occupied research camps for more in-depth site assessment.

Species composition

Species composition can be measured more finely with a small quadrat placed in continuous vegetation (water areas should be excluded). Quadrat size is 50 cm x 50 cm (0.25 m^2) with 10cm by 10 cm cells marked with string. Each cell of the 25 cells is scored for the presence of each plant species or functional group, and other cover types (bare sediment and rock). Up to five quadrats can be done in each vegetation zone if time allows. Data yielded by this method are frequency of occurrence

Vegetation Height

If insufficient vegetation height data are recorded along the transect as described in Ground Cover (i.e., $n \leq 20$ points), then additional vegetation height can be measured in the species composition quadrats. Maximum height of the dominant forage species in each cell should be recorded.

Grazing and Flowering Activity in Tall Sedge and Grass Tussocks

Additional information on grazing and flowering can be collected in tall sedge/grass communities. Select up to 10 clumps of the dominant forage species in which the number of shoots can be counted easily (i.e. about 30 shoots per clump). Each clump should be approximately 30 m apart. Within each clump count the number of grazed and ungrazed among the 30 shoots and count the number of those shoots that have inflorescences.

Shoot-pulling

In visiting a site in spring, soon after snow melt and during or after arrival of geese at a site, evidence of shoot pulling will still be obvious.

At randomly selected points within an assessment site, four 50m ground transects positioned at 90^o angles to form a cross pattern are laid out with a tape, or walked using a modified step-point method (Rockwell et al. 2013, Peterson et al. 2013). Record approximate percent of graminoid shoots pulled in the immediate vicinity of each ~1m step. These ocular assessments of shoot-pulling should be rounded to the nearest of 0, 33, 66, and 100 percentage categories. Place a 50 cm x 50 cm ($0.25m^{2)}$ quadrat at position/step 0, 25, and 50m along each transect and take a close-up vertical photo of the vegetation for post-processing (see Rockwell et al. 2013).

Faecal densities

In sites where seasonal research camps are established, the seasonal patterns of use of different plant communities can be determined by setting up plots and sampling them repeatedly (i.e. once per week) throughout the summer. Sets of five 4 m x 4 m plots should be set up in different vegetation communities where vegetation is continuous. The procedure is the same as the rapid assessment (above) .

Tides may wash faeces from lower vegetation zones in late summer in inter-tidal areas. If the interval between counts becomes too long the faeces may dry out and be blown away. It is usually not possible to distinguish between faeces of different species, although if there are only two species of different body size are present, it may be possible based size (e.g. faeces from lesser snow geese tend to be smaller than those of larger Canada geese in southern Hudson Bay).

Optional Elements That Require Significantly More Time/Resources

In seasonally occupied research camps, or where extra staff are available at the accommodations (e.g. when there is an alternate crew member that stays back each day), measures that require processing time can be added to the routine. Chief amongst these is getting handle on the amount of forage available for birds.

Amounts of forage available for birds

Primary production is a key process in ecosystem functioning. It can be used as a measure of community status or health. Ideally **annual net primary production**, defined as the amount of vegetation biomass that has been produced over the course of a growing season, would be measured. However, its measurement at the landscape level is very difficult, and in the assessment of goose habitats in the subarctic and arctic, it would require exclosures or a time series and is only suitable for seasonally occupied research and monitoring camps. **Standing Crop,** defined as the amount of live biomass present at a given time, is a more practical measure of production and it will provide a method of comparison across sites with varying goose use, in combination with other measures. It can also be used as a measure of the amount of forage available. Although production is occurring both above-ground and below-ground, in a rapid assessment situation only above-ground standing crop will be measured for two reasons: 1) because it is what is readily available and used by geese by grazing methods and 2) the measurement of below-ground biomass is difficult and time-consuming and not amenable to the rapid assessment objective. It is important to note that standing crop greatly underestimates annual primary production in some situations, e.g. salt marshes, because of the process botanists call overcompensation. Overcompensation by plants occurs when the response to herbivory is the prolonged continuous production of new leaves and shoots using the readily available nutrients (e.g. soluble nitrogen) provided in the faeces of the geese. In freshwater arctic graminoid habitats, there is evidence that overcompensation does not occur, thus standing crop in an ungrazed sward may be a good measure of annual primary production, and comparison of grazed and ungrazed swards can be a good measure of the annual off take by herbivores.

Measurements of standing crop of short graminoid vegetation (1) *Puccinellia phryganodes* / *Carex subspathacea,* (2) *Festuca rubra* / *Calamagrostis deschampsioides,* and (3) *Dupontia fisheri* / *Poa arctica* / *Alopecurus alpinus*). **Caution:** Standing Crop measurement requires some amount of field processing of turf samples (see below). All measurements of dry mass should be scaled up to 1 m^2 for comparison across sites and among communities.

1. Six to twelve turf samples should be collected at each site. These should be taken at least 30 metres apart to prevent pseudo replication. Circular cutting tools with an area of 100 cm^2 (fashioned from galvanized metal) can be used. However, another method is to cut a 12 cm x 12 cm turf at random using a wide bladed sturdy kitchen knife on each occasion the plot is visited (the turf depth should be about 1.5 cm). It is easier to cut a turf of this size and trim later to 10 x 10 cm. Place the turf in a zip lock sandwich container or bag and return to camp, or to the laboratory. If using bags, the samples should NOT be stacked on top of each other as compression makes processing more difficult. They should be stored in a cool, shady place until processing and processed within **24 hours** of collection (because they will continue to grow while the turf is intact in soil).

2. Field processing. Cut the vegetation from the turf with small scissors. Cut at soil or moss level, do not include soil particles or bits of moss. The cutting level should consistent. The plant material that is cut can be treated in two ways (dry or wet) depending on time and resources.

3. Dry treatment: remove dead plant litter, separate living plant material (it can be separated into different species, depending on objectives but is not essential). Place the groups of plant material in small envelopes, ends open. If heating is available, dry at 50°-70°C for 5 days and weigh to nearest mg, save samples. If no heating is available, air-dry samples in the field. On return to a laboratory, oven-dry the samples before weighing (see Jefferies et al 2008 for further details). Express results as g m^2 of dry plant material (living). Note: it is important to keep these samples as clear of soil and silts as possible.

4. Wet treatment: place plant material in a shallow tray of water (3-4 cm deep). Swish material in water to remove silts and soil particles. Dead material will often sink to the bottom; remove dead material onto filter paper or paper towel. Remove living material (usually floating) to labeled (with heavy pencil or waterproof marker) filter papers using forceps, or an aquarium net. Species can be separated by species again, but this is not essential. Plant material is transferred from the net to the paper with forceps. Place each filter paper fully folded in an envelope, labeled with date and location of collection, collector, species or functional group, etc. Dry and weigh plant tissue as in step 3 above. This washed material is best for analyses of nitrogen content or amounts of soluble carbohydrates in tissues.

5. Where there is continuous vegetation cover and season long measurement is possible, permanent sampling plots (4 x 4 m) can/should be established in replicates of five. Within each plot a 100 cm^2 sample should be taken on a weekly basis. If weekly sampling is not achievable, samples should be taken whenever possible, even if the sampling interval is monthly or more.

6. One-time only measures of Standing Crop should be taken at or near peak standing crop which is in late July or early August depending on location. This is convenient timing as many/most goose banding is done at about this stage of the season. In a heavily grazed situation this will severely underestimate NPP, because of the earlier removal of production throughout the growing/grazing season, but it will serve as a relative index of grazing pressure across sites and seasons.

Comparison of standing crop of vegetation in grazed and ungrazed swards of short graminoids

1. Besides the measurement of standing crop of grazed plots (above), similar measurements can be made in pairs of exclosed and ungrazed plots. This method is only applicable where a season long research camp is established and where objectives include establishing rates of goose consumption and compensating growth by grazed plants.

   The plots can be any convenient size (e.g., 1 m x 1 m when fewer than 5 samples are to be taken over a season), larger if more sampling is anticipated, such as over more than 1 season) and at least five exclosures should be put in position in each community to allow for calculation of means and variances. The smaller size (1 m x 1 m) is usually sufficient and they are less likely to be disturbed or smashed by polar bears, caribou or other large mammals. smaller sizes can be used if only one sample at beginning and end of season is planned, but avoid such small sizes that plants grow to a height which geese can reach by poking through. Each pair of grazed and ungrazed plots should be at least 50 m apart from the adjacent pair. We use chicken wire (height c. 18"). The 1 m x 1 m exclosures can be prepared in camp. Corners can be supported with wire pegs (e.g. forestry markers) or wooden lath (if available). Wire should be touching the ground to prevent geese from getting under to graze. The exclosures can be flattened and transported easily in a helicopter. In larger exclosures it is usually necessary to put strings across the top, once the exclosures are in place, or to use raspberry cane netting to keep geese out (1 m x 1 m). In most cases, remove the exclosures at the end of the season. Samples are taken from each of the five exclosures and the results can be compared with results from adjacent grazed swards as g m^2.

Standing crop in moderate to tall graminoid vegetation

Tall graminoid vegetation is widespread in some sub-Arctic and Arctic wetlands. Species include *Carex aquatilis*, *C. aquatilis (stans)*, *Calamagrostis canadensis*, *Eriophorum angustifolium*, *E. spissum* and *E. scheuchzeri.*

1. Measurement of standing crop as an index of food available is less satisfactory for these types of communities, because much of the tissues is of no value to the geese as forage. However, measurement of standing crop as an index of cumulative impact of goose grazing has value. Using a 20cm x 20 cm to 30 cm x 30 cm flexible sampling frame, cut all vegetation with a shears at the base (the white tissue below the chlorophylous tissue) which may require pulling the moss layer aside. Keep shoots intact (i.e., do not cut into smaller pieces). Wash each sample for about 30 seconds (no longer). Drain the plant material of excess water (e.g. in a salad spinner). Separate plant material by functional group, if desired. Place the sample in a brown paper bag, labeled with collection site, date, type of sample, collector, etc. Air dry the sample for one week in the field or in a drying oven. For additional details, see Jefferies et al. (2008).

Other useful information

Plant voucher specimens. Most of the locations where sampling will be done are remote and seldom visited, or not visited by botanists on a regular basis. Consideration should be given to collection of plant voucher specimens to be deposited with a museum such as the National Museum of Canada. When species composition is part of the protocol, any plant that is unknown or of uncertain identity should be collected, pressed and submitted to an authority for identification. Many of these will be grazed or missing parts, thus an attempt should be made to find individuals that have flowering or fruiting parts to collect along with the grazed specimen.

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Images of Goose Herbivory

Figure 1. “Phalanx” grubbing by snow geese in *Puccinellia phryganodes* turf.

Figure 2. Patch grubbing by Canada geese in *Festuca rubra*.

Figure 3. Canada goose grubbing of graminoids, showing incidental damage to moss.

Figure 4. Canada goose grubbing in *Festuca rubra*. The panel on the left shows current year damage with dried remnants lying in situ; the panel on the right shows damage from a previous year, with dried remnants gone, a hypersaline algal crust, and new *Senecio congestus* growth in disturbed area.

Figure 5. Individual “beak-hole” grubbing.

Figure 6. Heavily grazed *Festuca rubra* remnant patch, showing effects of cumulative grubbing from previous years along the edges.

Figure 7. Post-grubbing landscape with hyper-saline soils, *Salicornia* spp. (red surface), and dead *Salix* spp.

Figure 8. Post-grubbing landscape with wet *Senecio congestus* disturbance community.

Figure 9. Post-grubbing landscape with well-drained *Senecio congestus* disturbance community, with algal crusts in the foreground.

Figure 10. Windrows of *Senecio congestus* in turbid ponds (upper panels); uprooted individual *S. congestus* plants (lower panel). Plants on the left without roots have been uprooted by geese; plants on the right were uprooted and washed to show the fine roots that are eaten by the geese.

Figure 11. *Hippuris* spp. uprooted by Canada geese “cratering” in a pond.

Figure 12. Spring shoot-pulling by Canada geese.

Figure 13. Spring shoot-pulling by snow geese.

Figure 14. Discarded shoots of *Carex aquatilis* after seasonal water level decline.

Figure 15. Results of cumulative shoot-pulling by snow geese as demonstrated by the lush growth within the exclosure.

Figure 16. Results of exclosure experiment showing difference in above-ground biomass between grazed patches (far left), patches protected for seven weeks (middle), and patches protected for two growing seasons (far right).