CONSERVATION OF THE ENDANGERED LIMESTONE ENDEMIC SALIX JEJUNA; EFFECTS OF ANTHROPOGENIC DISTURBANCE ON HABITAT AND LIFE HISTORY

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CONSERVATION OF THE ENDANGERED LIMESTONE ENDEMIC *SALIX JEJUNA*; EFFECTS OF ANTHROPOGENIC DISTURBANCE ON HABITAT AND LIFE HISTORY

by

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Abstract

Anthropogenic disturbance has been shown to have negative impacts on the recovery of endangered or rare species. Specific recovery objectives for *Salix jejuna*, an endangered prostrate shrub endemic to the globally rare limestone barrens habitat of Newfoundland (Canada), include assessing the population dynamics of natural populations, understanding limiting factors, defining threats and mitigating controllable threats where possible. As a large portion of *S. jejuna*'s habitat has been anthropogenically-disturbed, understanding the effects of disturbance on species persistence are central to promoting species recovery.

An assessment of habitat features revealed that anthropogenically-disturbed substrates were more homogeneous than undisturbed, natural substrates, with more gravel, less exposed bedrock, decreased soil moisture, and increased nutrient content. Populations resident on anthropogenically-disturbed habitats tended towards a more "annual" dynamic, with a greater proportion of seedlings, lower levels of clonal growth, and a younger median age compared with populations on naturally-disturbed substrates. Therefore, specific recovery plans for *S. jejuna* should include the elimination of continual disturbances such as off-road vehicle use and the active restoration of disturbed habitat to restore natural ecosystem processes, to reflect adjacent undisturbed natural habitat, and to promote the clonal reproductive traits of natural populations.

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1.0 GENERAL INTRODUCTION

There are over 12,000 plant species listed on the International Union for the Conservation of Nature 2008 Red List, with approximately 8,000 species categorized as critically endangered, endangered, or vulnerable. Less than 10% of these listed species are well documented, including 11 species in the Salicaceae (IUCN 2009), five of which are also listed under the Canadian Species at Risk Act (2003). Consequently, recovery planners worldwide are faced with the challenge of developing effective *in situ* conservation plans for endangered species management, frequently with little available information on the habitat requirements of the target species or the factors affecting species persistence (Hockey & Curtis 2008).

An important tool in the recovery planning and management of species at risk of extinction is the use of population viability models (PVA) (Schemeske et al. 1994, Beissinger and Westphal 1998, Morris et al. 2002). Biological information such as the factors that limit or influence species distribution and life history traits (Schmeske et al. 1994; Gonzàlez-Benito et al. 1995; Kluse and Doak 1999) are the basis for PVA's which provide a critical evaluation of the viability of threatened species (Harvey 1985; Menges 1990; Oostermeijer et al. 1996; Maschinski et al. 1997, 2006; Yates et al. 2007). Furthermore, without accurate biological information, appropriate monitoring strategies cannot be established, while predictions of species persistence will be difficult for recovery planners to assess (Ohara et al. 2006).

Recovery planning is a complex process due to the numerous factors involved (e.g., biological, legislative, socio-economic) (NRWG 2007) and by the high degree of global habitat alteration (Sanderson et al. 2002) which is thought to inhibit the recovery potential of endangered species (Kerr and Deguise 2004). Habitat loss and degradation is of principle concern when recovery is centered around narrowly distributed endemic plant species whose restricted nature limits their ability to adapt to changing environments (Krukeberg & Rabinowitz 1985), making them especially vulnerable to anthropogenic change (Fielder and Ahouse 1992).

Myers et al. (2000) estimate that as much as 44% of the world's endemic plant species are found in areas of high diversity known as 'hot spots'. These endemic plant species once survived on 12% of the global land surface but only 1.4% of their historical habitat remains intact (Myers et al. 2000). Today, one-half to two-thirds of all threatened endemic plants are confined to these diminishing hotspots (Brooks et al. 2002). In Canada, habitat loss is considered most severe in biodiversity hotspots (Kerr & Deguise 2004). More specifically, in a 2004 Canadian study, Kerr and Deguise estimated that of the 243 species at risk examined, 113 species had less than 33% of their natural habitat remaining (i.e., no anthropogenic modification), 58 had less than 10% remaining, and l6 species had no natural habitat detected.

Endemic species often continue to inhabit modified (i.e., degraded) habitat, suggesting that planners should consider the conservation value of these habitats in recovery planning. Though research in this area is limited, previous research has shown that populations of endangered or threatened endemics resident on anthropogenically-disturbed habitat have decreased population growth rate (Ureta & Martorell 2009), decreased persistence (Noel 2000), increased susceptibility to insect pests (Squires 2010), and increased likelihood of hybridization in nearby natural populations of the same species (Lamont et al. 2003; Parsons and Hermanutz 2006). These changes, mediated by anthropogenic disturbance, have long term effects on population sustainability and often require human assistance to restore natural habitat processes and populations back to their natural state.

Prior to active restoration, an evaluation of features within undisturbed and disturbed habitat must be attained such as: vegetation structure, plant species composition, ground cover, and condition (Miller and Hobbs 2007). This evaluation allows recovery planners to develop appropriate restoration goals (Hobbs and Norton 1996) and to later evaluate the impacts of restoration on the entire vegetative community (Brewer and Menzel 2009). Having the information available to effectively carry out this restoration process is especially important when restoration includes the rehabilitation of endangered, endemic populations inhabiting globally rare habitat.

Study Area

The limestone barrens of the island of Newfoundland (Canada) are considered a hot spot for plant diversity, supporting three listed endemics (Species at Risk Act 2003) and 114 of the province's 271 rare plant species (Bouchard et al. 1991). Located on the Great Northern Peninsula of the island of Newfoundland, within the Strait of Belle Isle Ecoregion, the northern limestone barrens are part of a globally imperilled ecosystem known as limestone pavements which occur in places such as Sweden, Estonia, North America, Ireland and Britain. In North America these ecosystems are also commonly known as alvars, which consist of plant communities occurring on shallow soils over limestone bedrock (Lundholm and Larson 2003). In the Great Lakes region of Ontario (Canada), alvars harbour many provincially rare species (Belcher et al. 1992; Catling 1995; Schaefer and Larson 1997). What separates the limestone barrens of Newfoundland from alvars are the cryogenic processes (i.e., freeze-thaw processes) that shape the limestone barrens landscape (e.g., frost stripes, frost boils), creating tundra-like vegetation and providing natural disturbances in which many arctic-alpine plants rely upon for regeneration (Banfield 1983; Noel 2000; Sutton et al. 2006).

Limestone pavements and their unique plant communities have been susceptible to anthropogenic disturbance worldwide. The alvars of the Great Lakes region of Ontario have been threatened by quarrying and residential development (Catling and Brownell 1995; Reschke et al. 1999), while limestone pavements in Britain have been degraded by farmland conversion and removal of stone for decorative use in the horticultural market (Bennett et al. 1995). Further, the natural habitat of the limestone barrens of Newfoundland have been, and continue to be, subject to quarrying, road development, and off-road vehicle use (e.g., ATVs) (Anions 2001; Hermanutz et al. 2002; Djan-Chékar et al. 2003; Rafuse 2005).

Study Species

Salix jejuna Fernald (Barrens willow) is a narrowly distributed (linearly distributed by approximately 30 km) prostrate woody shrub endemic to a thin coastal strip of the northern limestone barrens on the island of Newfoundland (Figure 1.1). It is a member of the Salicaceae. In 2001, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated *S. jejuna* as endangered. It was later designated as endangered under the Newfoundland and Labrador *Endangered Species Act* in 2002 and under the Federal *Species at Risk Act* in 2003. It is considered critically imperilled globally, nationally, and provincially with G1, N1 and S1 designations, respectively (Nature Serve 2009).

S. jejuna is thought to be present in all known historic locations though much of its habitat has been severely degraded, primarily due to road construction and off-road vehicle use (Djan-Chékar et al. 2003; Rafuse 2005). It inhabits both naturally-disturbed (e.g., through frost activity) and anthropogenically-disturbed limestone barrens habitat. Greene (2002) described anthropogenically-disturbed limestone barrens habitat, within the distribution of the endemic *Braya longii* Fernald (endangered) and *B. fernaldii* Abbe (threatened), as lacking the clear natural disturbance patterns, such as frost stripes or frost boils that are found within undisturbed natural habitat. Anthropogenically-disturbed habitats also contained homogenous gravel substrates and low species diversity (Greene 2002; Rafuse 2005).

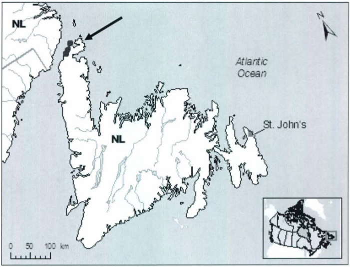

Figure 1.1 Map of the island of Newfoundland (Canada) and of the distribution of *Salix jejuna* (black dots; see arrow) on the Great Northern Peninsula {Environment Canada}. Exact locations cannot be outlined due of the endangered status of this species.

Conservation Efforts for Salix jejuna

The Government of Newfoundland and Labrador, in conjunction with its federal partners, Parks Canada, Environment Canada, and the provincial Limestone Barrens Species At Risk Recovery Team (LBSARRT), is responsible for securing the long term persistence of *S. jejuna* throughout its range, as described in the Barrens willow Recovery Strategy (Djan-Chékar et al. 2003).

The specific short-term recovery objectives which are designed to meet the long-term recovery goal for *S. jejuna* are outlined in the Recovery Strategy (Djan-Chékar et al. 2003) as follows: 1) assess and monitor the status of the natural population; 2) assess range and population dynamics of the natural population; 3) define threats and limiting factors and mitigate controllable ones; 4) lessen to the extent possible additional habitat loss and degradation due to human activities; and 5) implement a stewardship program with local residents and targeted groups (Djan-Chékar et al. 2003). The broad approaches to meet the recovery objectives for *S. jejuna* are outlined in Table AI.I.

Previous research has contributed to the recovery goal and objectives for *S. jejuna* and has focused on the development of *ex situ* conservation strategies such as maintaining a representative *ex situ* population (Memorial University of Newfoundland Botanical Garden) and the propagation of plants through tissue culture (Driscoll 2006). The present study will contribute to the recovery of *S.jejuna* by providing information that allows for the development of effective *in situ* conservation strategies, which supports the preservation of *S. jejuna* and the limestone barrens ecosystem as a whole. This study also contributes to our overall understanding of the life history and demographic response of woody clonal species to disturbance. These aspects have not been well studied to date.

Research Objectives

The objectives of this research were to better understand the impacts of disturbance on *S. jejuna* by: 1) examining the differences in substrate and vegetation characteristics between naturally-disturbed and anthropogenically-disturbed habitat (Chapter 2) and; 2) examining demographic parameters, including the relative importance of sexual and asexual reproduction within populations resident within both disturbance types (Chapter 3).

REFERENCES

Anions MFE (2001) COSEWIC status report on Barrens Willow, *Salix jejuna*. Committee on the Status of Endangered Wildlife in Canada. 24 pp. (Unpublished report)

Banfield C (1983) Climate. In: South RG (ed) Biogeography and Ecology of the Island of Newfoundland, Junk Publishers, Boston, USA

Beissinger SR, Westphal MI (1998) On the use of demographic models of population viability in endangered species management. The Journal of Wildlife Management 62:821-841

Belcher JW, Keddy PA, Catling PM (1992) Alvar vegetation in Canada: a multivariate description at two scales. Canadian Journal of Botany 70:1279-1291

Bennett AF, Bennett MR, Doyle P (1995) Paving the way for conservation? Geology Today May-June 98-100

Bouchard A, Hay S, Brouillet L, Jean M, Saucier I (1991) The rare vascular plants of the Island of Newfoundland. Syllogeus No. 65

Brewer JS, Menzel T (2009) A method for evaluating outcomes of restoration when no reference sites exist. Restoration Ecology 17:4-11

Brooks TM, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Rylands AB, Konstant WR, Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylor C

(2002) Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16:909-923

Catling PM (1995) The extent of confinement of vascular plants to alvars in southern Ontario. Canadian Field Naturalist 109:172-181

Catling PM, Brownell VR (1995) A review of the alvars of the Great Lakes region: distribution, floristic composition, biogeography and protection. Canadian Field Naturalist 109:143-171

Djan-Chékar N, Hermanutz L, Ballam D, Bell T, Brazil J, Mann H, Maunder J, Meades SJ, Nicholls W, Soper L, Yetman G (2003) Recovery strategy for the Barrens Willow (*Salix jejuna* Fernald). Inland Fish and Wildlife Division, Government of Newfoundland and Labrador, Corner Brook, Canada 11 pp.

Driscoll J (2006) *Ex situ* conservation protocols for the rare plants *Braya longii* (endangered), *Braya fernaldii* (threatened) (Brassicaceae) and *Salix jejuna* (endangered) (Salicaceae), endemic to the Limestone Barrens of Newfoundland. M.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Fiedler PL, Ahouse JJ (1992) Hierarchies of cause: toward an understanding of rarity in vascular plant species. In: Fiedler PL and Jain SK (eds) Conservation biology: The theory and practice of nature conservation, preservation and management, Chapman & Hall, New York, USA

Gonzàlez-Benito E, Martin C, Iriondo JM (1995) Autoecology and conservation of *Erodium paularense* FDEZ, GLEZ & IZCO. Biological Conservation 72:55-60

Greene S (2002) Substrate characteristics of *Braya* habitat on the limestone barrens, Great Northern Peninsula, Newfoundland. B.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Harvey HJ (1985) Population biology and the conservation of rare species. In: Festschrift A, for Harper JL (ed. J. White) Studies on plant demography, Academic Press, London, Britain

Hermanutz LA, Mann H, Anions MFE, Ballam D, Bell T, Brazil J, Djan-Chékar N, Gibbons G, Maunder J, Meades SJ, Nicholls W, Smith N, Yetman G. (2002). National Recovery Plan for *Braya longii* and *B. fernaldii*. National Recovery Plan No. 23. Recovery of Nationally Endangered Wildlife (RENEW), Ottawa, Ontario, Canada.

Hobbs RJ, Norton DA (1996) Towards a conceptual framework for restoration ecology. Restoration Ecology 4:93-110

Hockey PAR, Curtis OE (2008) Use of basic biological information for rapid prediction of the response of species to habitat loss. Conservation Biology 23: 64-71

IUCN 2009. IUCN Red List of Threatened Species. Version 2009.1. <www.iucnredlist.org>. Accessed 14 June 2009.

Kerr JT, Deguise I (2004) Habitat loss and the limits to endangered species recovery. Ecology Letters 7:1163 - 1169

Kluse J, Doak DF (1999) Demographic performance of a rare California endemic, *Chorizanthe pungens* var. hartwegiana (Polygonaceae). American Midland Naturalist 142:244-256

Kruckeberg AR, Rabinowitz D (1985) Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics 16:447-479

Lamont BB, He T, Enright NJ, Krauss SL, Miller BP (2003) Anthropogenic disturbance promotes hybridization between *Banksia* species by altering their biology. Journal of Evolutionary Biology 16:551-557

Lundholm JT, Larson DW (2003) Relationships between spatial environmental heterogeneity and plant species diversity on a limestone pavement. Ecography 26:715-722

Maschinski J, Baggs JE, Quintana-Ascencio, PF, Menges ES (2006) Using population viability analysis to predict the effects of climate change on the extinction risk of an endangered limestone endemic shrub, Arizona Cliffrose. Conservation Biology 20:218-228

Maschinski J, Frye R, Rutman S (1997) Demography and population viability of an endangered plant species before and after protection from trampling. Conservation Biology 11:990-999

Menges E (1990) Population viability analyses in plants: challenges and opportunities. TREE 15:51-56

Miller JR, Hobbs RJ (2007) Habitat restoration – do we know what we're doing? Restoration Ecology 15:382-390

Morris WF, Bloch PL, Hudgens BR, Moyle LC, Stinchcombe JR (2002) Population viability analysis in endangered species recovery plans: Past use and future improvements. Ecological Applications 12:708-712

Myers N, Mittermeier RA, Mittermeirer CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858

National Recovery Working Group. 2007. Recovery Handbook (ROMAN). 2007-2008 Edition, April 2007. Recovery of Nationally Endangered Wildlife, Ottawa, Ontario, Canada

Noel L (2000) The effect of disturbance on the seedling recruitment and persistence of *Braya longii* and *Braya fernaldii*. B.Sc. Thesis. Department of Biology, Memorial University, St. John's, Newfoundland, Canada

Ohara M, Tomimatsu H, Takada T, Kawano S (2006) Importance of life history studies for conservation of fragmented populations: A case study of the understory herb, *Trillium camschatcense*. Plant Species Biology 21:1–12

Oostermeijer JGB, Brugman ML, De Boer ER, Den Nijs HCM (1996) Temporal and spatial variation in the demography of *Gentiana pneumonanthe*, a rare perennial herb. The Journal of Ecology 84:153-166

Parsons K, Hermanutz L (2006) Conservation of rare, endemic braya species (Brassicaceae): Breeding system variation, potential hybridization, and human disturbance. Biological Conservation 128:201-214

Rafuse G (2005) The impact of off-road vehicles on the Limestone Barrens habitat and resident plants endemic to the Great Northern Peninsula, Newfoundland, Canada. B.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Reschke C, Reid R, Jones J, Feeney T, Potter H (1999) Conserving Great Lakes alvars. The Nature Conservancy, Chicago, IL, USA

Sanderson EW, Malanding J, Levy MA, Redford KH, Wannebo AV, Woolmer G (2002) The human footprint and the last of the wild. BioScience 52: 891-904

Schaefer CA, Larson DW (1997) Vegetation, environmental characteristics and ideas on the maintenance of alvars on the Bruce Peninsula, Canada. Journal of Vegetation Science 8:797–810

Schemeske DW, Husband BC, Ruckelshaus MH, Goodwillie C, Parker IM, Bishop JG (1994) Evaluating approaches to the conservation of rare and endangered plants. Ecology 75:584-606

Species at Risk Act (2003) Species at Risk Act, Statutes of Canada. Canada Gazette. Queen's Printer for Canada, Ottawa, Ontario

Squires S (2010) Insect pests and pathogens compromise the persistence of two endemic and rare Braya (Brassicaceae). PhD Thesis. Department of Biology, Memorial University, St. John's, Newfoundland, Canada.

Sutton JT, Hermanutz L, Jacobs JD (2006) Are frost boils important for the recruitment of Arctic-Alpine plants? Arctic, Antarctic & Alpine Research 38:273-275

Ureta C, Martorell C (2009) Identifying the impacts of chronic anthropogenic disturbance on two threatened cacti to provide guidelines for population-dynamics restoration. Biological Conservation 142:1992-2001

Yates CJ, Ladd PG, Coates DJ, McArthur S (2007) Hierarchies of cause: understanding rarity in an endemic shrub *Verticordia staminosa* (Myrtaceae) with a highly restricted distribution. Australian Journal of Botany 55:194-205

Co-Authorship Statement

All manuscripts in this thesis were co-authored with Dr. Luise Hermanutz. In all instances I was the principal contributor to project design and proposal, implementation of the field research component, analysis of the data and manuscript preparation.

2.0 HOW ANTHROPOGENIC DISTURBANCE AFFECTS THE RECOVERY OF *SALIX JEJUNA* (ENDANGERED) AND ITS GLOBALLY RARE LIMESTONE HABITAT

2.1 INTRODUCTION

The recovery potential of endangered and threatened species is limited by the high prevalence of anthropogenically-modified habitat (Kerr and Deguise 2004), making habitat loss and fragmentation the primary cause of species extirpation (Alonso et al. 2001; Brooks et al. 2002). Because of their unique habitat, restricted distributions, and requirement for particular disturbance regimes, endemic rare plant species are especially vulnerable to anthropogenic change (Fielder and Ahouse 1992; Maschinski et al. 2004). These endemic plant species once survived on 12% of the global land surface but only 1.4% of their historical habitat remains intact (Myers et al. 2000).

To ensure long term persistence of endangered or threatened endemic species, recovery efforts frequently need to include the restoration of degraded habitat (Kerr and Deguise 2004). And, as rare plant populations often inhabit geographically delineated communities or geologically unique ecosystems, restoration of the target species often coincides with restoration of endangered habitat.

However, restoration efforts are often carried out without proper knowledge of habitat characteristics or requirements related to the target species or target ecosystem (Miller and Hobbs 2007). Furthermore, restoration frequently proceeds without a specific restoration goal or the appropriate information required to assess restoration success (Hobbs and Norton 1996).

In their recent review, Miller and Hobbs (2007) suggest that a full evaluation of habitat features must be attained prior to restoration efforts such as: vegetation structure, plant species composition, ground cover, and condition. Biological surveying of anthropogenically-disturbed habitat as well as adjacent undisturbed natural habitat, or a "reference" site, can improve the restoration process and allows for effective evaluation of project goals. However, the Society for Ecological Restoration International (SER) (2004) suggests that restoration practitioners should consider variation among reference sites, indicating that multiple reference sites may be required. Moreover, the SER suggests nine characteristics that restoration practitioners can use to determine if a restored system has "recovered"; one of which is the elimination or reduction of potential threats.

The "limestone barrens" of Newfoundland are part of a globally imperilled habitat, more commonly known as limestone pavements. Limestone pavements occur in such places as Sweden, Estonia, North America, Britain and Ireland. In the Great Lakes region of Ontario (Canada), limestone pavement alvars harbour many provincially rare species (Belcher et al. 1992; Catling 1995; Schaefer and Larson 1997) and within the province of Newfoundland and Labrador (Canada), the limestone barrens are considered a hot spot for plant diversity, supporting three endemics and 114 of the province's 271 rare plant species (Bouchard et al. 1991).

The unique flora of limestone pavements has been threatened by quarrying and residential development in the alvars of the Great Lakes of Canada (Catling and Brownell 1995; Reschke et al. 1999) and throughout the limestone pavements of Britain (Goldie 1993). In Britain, only 3% of limestone pavement remains intact (Anon 2001). This is primarily due to farmland conversion and removal of stone for decorative use in the horticultural market (Bennett et al. 1995). In Newfoundland, during the last several decades, road development, quarrying, and off-road vehicle use (e.g., all terrain vehicles (ATVs)) have altered much of the habitat for three SARA (Species at Risk Act 2003) listed species endemic to the limestone barrens (Anions 2001; Hermanutz et al. 2002; Djan-Chékar et al. 2003; Rafuse 2005). In fact, Hermanutz et al. (2009) estimates that degraded limestone barrens landscapes account for as much as 31% of habitat within narrowly distributed endemic populations of endangered and threatened species of *Braya*.

Anthropogenic disturbance has been shown to affect populations of rare endemic plant species adversely within the limestone barrens of Newfoundland; disturbed populations of *Braya* have lower population persistence (Noel 2000) and higher rates of mortality due to increased risk of infestation and infection (Squires 2010). In a recent study, Parsons and Hermanutz (2006) demonstrated that anthropogenic disturbance also increased the likelihood of hybridization in localized populations of *Braya* growing on natural substrates. In similar arctic-tundra communities, anthropogenic disturbance has altered species diversity (Sumina 1994; Forbes et al. 2001), decreased plant cover by at least 40 to 50%

(Kevan et al. 1995; Monz 2002), and changed substrate conditions, such as soil nutrients (Kevan et al. 1995; Auerbach et al. 1997), soil moisture (Driscoll 2006), and soil temperature (Chapin and Shaver 1981).

Salix jejuna (Barrens willow) Fernald (Salicaceae) is a prostrate shrub endemic to the limestone barrens of Newfoundland (Canada). In this arctic-like climate (Banfield 1983; Donato 2005) it inhabits naturally- (via frost activity) and anthropogenically-disturbed soils and is restricted to a 30 kilometre linear distribution (Djan-Chékar et al. 2003). Previous research on *S. jejuna* has focused on developing *ex situ* conservation strategies, such as the development of propagation techniques and the maintenance of an *ex situ* population (Driscoll 2006). However, little research has been conducted to allow for the development of effective *in situ* conservation strategies such as the completion of biological surveys to determine threats and their impacts, as well as identifying and restoring disturbed habitat within species range, as outlined in the *S. jejuna* Recovery Strategy (Djan-Chékar et al. 2003).

Therefore, the overall goal of this study was to determine the impact of disturbance on *S. jejuna* in order to contribute to a better understanding of optimal habitat and to provide information which is useful when developing conservation plans which include the restoration of disturbed habitat. Differences in substrate and vegetation were studied in naturally-disturbed (via frost activity) and anthropogenically-disturbed habitat. Habitat variation was documented throughout species range and habitat parameters (e.g., % total plant cover, %

species cover, substrate type) that influence the abundance of *S. jejuna* were determined.

2.2 METHODS

Study sites

Field surveys encompassed the entire global range of *S. jejuna* (Barrens willow) within the northern limestone barrens of the Great Northern Peninsula (island of Newfoundland, Canada), which lies within the Strait of Belle Isle ecoregion. Populations of *S. jejuna* are patchily distributed along a 30 km stretch of coastline (Djan-Chékar et al. 2003). The limestone barrens are characterized by a cool, wet, and windy climate that supports tundra-like vegetation (Banfield 1983; Donato 2005). The substrate is characterized by bare limestone bedrock, limestone heath, and localized patches of thin glacial and marine sediment (Grant 1992).

In the past, much of the limestone barrens habitat was disturbed during the process of road construction and limestone quarrying; in the last 10 years, off-road vehicles such as ATVs have caused considerable habitat degradation. The timing of larger scale disturbance is not known but it is likely to have occurred between 1975 and 1980, during a major period of road construction (Hermanutz et al. 2002), with local disturbances such as ATV damage ongoing across the region. To understand the effect of disturbance type on the community context of *S. jejuna*, substrate and vegetation characteristics were compared on both naturally- (undisturbed by human activity though naturally disturbed by cryogenic processes) (N=5 sites) and anthropogenically-disturbed (N=3 sites) habitat, referred to as "disturbed" (Table 2.1). Natural disturbance can be observed in the form of patterned ground (e.g., frost boils, frost stripes) and limestone bedrock shattering. The selected sites represent populations throughout the entire range of the species as well as populations of *S. jejuna* that were sufficiently large and dense to obtain an appropriate sample size. All sites were classified visually according to disturbance intensity (amount of anthropogenic disturbance; Rafuse 2005) on the basis of physical evidence at the time of sampling. Physical evidence included degree of soil compaction (visual estimation), amount of vehicle damage (number and depth of tracks), and proximity to continual disturbance source (e.g., road). Disturbance intensity was classified on an ordinal scale from 0 to 3 where 0= no indications of anthropogenic disturbance, 1 = low, 2= moderate, and 3= severe, following the protocol of McIntyre and Lavorel (1994).

Table 2.1 *Salix jejuna* study site information indicating disturbance type (N=natural, D=anthropogenic) and intensity of anthropogenic disturbance (0= none, 1= low, 2= moderate, 3= severe), on the limestone barrens of Newfoundland (Canada). Sites are listed from most southerly to most northerly; see methods for details on sampling.

Site Name	Disturbance Type	Description of Disturbance	Disturbance Intensity	Site Area (m^2)
BKD-D	Anthropogenic	Organic layer still removed, some evidence of patterned ground	1	265
BK1-N	Natural	Frost boils present; naturally shattered limestone; highly wind eroded	0	740
BK39-N	Natural	Frost stripes present; Highly wind eroded	0	670
BHN-N	Natural	Largely exposed bedrock; highly wind eroded; most coastal site	0	945
CND-D	Anthropogenic	Organic layer completely removed, rounded coarse sediment, vehicle tracks, continual exposure to vehicle dust	3	920
CNC-N	Natural	Largely exposed bedrock; Low wind erosion	0	330
CNA-N	Natural	Largely exposed bedrock; Low wind erosion	0	450
CNE-D	Anthropogenic	Organic layer partially removed, vehicle tracks, rounded coarse sediment	2	280

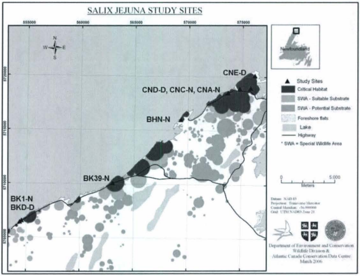

Figure 2.1 Map displaying the location of all *Salix jejuna* study sites, indicating disturbance type (N=natural, D=anthropogenic), on the limestone barrens of Newfoundland (Canada).

Substrate and Vegetation sampling

At each site, 6-8 line transects 20-30 m long were selectively positioned to cover approximately 80% of the area occupied by *S. jejuna*. Study plots (1m^2; 100 cells) were then located at every other metre along the line transects. The number of plots varied among sites (n= 40 to 83), depending upon the area of the site, site homogeneity and the density of the target species (Chapter 3). Populations of *S. jejuna* were clearly distinguishable from local vegetation therefore, the area of occupied habitats was easily determined with a measuring tape.

Field surveys took place from mid-June to early-August, 2006, and again in mid-July 2007. All sampling was conducted under appropriate government permits. Within each study plot the percent of ground covered was visually estimated (to the nearest 5%) for each substrate class. The following substrate classification system was used (modified from Wentworth (1922)): silt/clay (very fine, moist material, soft to touch, < 1mm), sand (grains visible, 1-2 mm), granules & pebbles (2–64 mm), cobbles (64-256 mm), boulders (>256 mm), and exposed bedrock.

Soil samples were collected for determination of soil moisture, nutrient content and particle size analysis. Random samples were collected from each site, using a soil core to 10 cm depth, on July 3, 2006 (20 samples) and August 8, 2006 (10 samples). Soil moisture was determined gravimetrically after the samples had been air dried for four weeks (Allen 1990).

Of the 20 samples collected on July 3, 2006, three from each site were randomly selected for nutrient analysis. Due to provincial permit restrictions associated with endangered species the amount of soil collected on each site was limited; therefore conventional methods of pooling samples could not be done as samples were required for other analyses. Samples were analyzed for total nitrogen (%), Ca, P, K and Mg using the Mehlich III extraction method at the Soil and Feed Laboratory, Agriculture Canada, St. John's, Newfoundland.

Particle size analysis was conducted on 10 random samples from each site using a standard wet-sieving protocol which determines the percent of silt and clay particles (< 62.5 µm) in each sample (Allen 1990). All samples were then dry sieved and the percent of very fine to fine sand (62.5 μm -0.25 mm), medium sand (0.25 mm - 0.50 mm), coarse to very coarse (0.50 mm- 1 mm), granules (2 mm - 4 mm) and pebbles (>4 mm) was determined (Wentworth 1922).

The presence/absence of all vascular and non vascular species was recorded within all study plots. Percent cover (to the nearest 5%) was estimated for the following functional plant groups: woody, herbaceous, bryophytes, lichens, and bare ground as well as for each individual vascular plant species (excluding grasses and sedges). Plots surveyed near the beginning of the growing season were revisited to account for the establishment of species which may not have been visible at the earlier sampling date.

Statistical Analysis

All statistical analyses were performed in SAS® version 9.1 (SAS Institute Inc. 1996). Data were analyzed for normality, independence and homogeneity. If assumptions were not met for a general linear model than a generalized linear model was applied (Little et al. 2002). Where the response variable consisted of proportional data (e.g., % cover) the logistic regression using generalized linear model was used with binomial distribution (Lewis 2004). For all analyses, site was considered a fixed effect, nested within disturbance (natural vs. anthropogenic).

Species richness (S), Shannon diversity index (H') and evenness (J) (Magurran 1988) were calculated to investigate the effect of disturbance type on plant community composition. The Shannon diversity index was calculated using species covers as abundance values. Evenness was calculated as H'/ln S, where S is the number of species (Magurran 1988).

To investigate the effect of vegetation (e.g., % woody cover, % herbaceous cover) and substrate cover (e.g., % silt cover, % sand cover) on *S. jejuna* cover, binomial logistic regression analyses were performed on pooled data. Spearman rank correlations were also performed to evaluate whether *S. jejuna* had any significant associations with other plant species.

Finally, a principle components analysis (PCA) was performed to compare the vegetation and substrate cover between disturbance types and to examine the variation among sites within each disturbance type. The PCA included the functional plant groups (e.g., % woody cover, % herbaceous cover) as well as substrate classes for percent cover (e.g., % silt cover, % sand cover).

2.3 RESULTS

Influence of disturbance type on substrate

Substrate of both natural and disturbed *S. jejuna* sites is characterized by limestone material but varies greatly in form and pattern (Figure 2.1). Natural sites have more exposed bedrock (natural = 22.6% ± 7.14%; disturbed = 0.8% ± 0.35%; df=1, χ^2=808.55, p<0.001) and less area covered by gravels (*granules*; natural = 31.0% ± 4.26%; disturbed = 47.8% ±15.78%; df=1, χ^2=714.67, p<0.001; *cobbles*; natural = 7.5% ± 1.73%; disturbed = 11.8% ± 2.81%; df=1, χ^2=931.55, p<0.001). Both natural and disturbed sites were found to have similar ground covered by smaller particles (e.g., *silt* df=1, χ^2=0.14, p=0.712; *sand* df=1, χ^2=3.66, p=0.056) (Table 2.2) and boulders (df=1, χ^2=1.62, p=0.2036).

Textural analysis revealed similar results with disturbed sites having an abundance of larger particles; 6.9% greater coarse sand, 2.7% greater granule and 14.4% more pebble content than natural sites (df=1, χ^2=24.52; χ^2=165.43; χ^2=81.33; p<0.001, respectively). In contrast to percent cover data, textural analysis indicates natural sites have 19.9% more fine and 5.6% more medium sand than disturbed sites (Figure 2.2; df=1, χ^2=425.30; χ^2=37.25; p<0.001, respectively). Silt content was not affected by disturbance type (df=1, χ^2=0.59, p=0.4406).

Of the soil nutrients determined, total % nitrogen (df=1, χ^2=165.43, p<0.001) and phosphorus ($F_{1,6}$=8.012, p=0.0299) were most affected by disturbance type (Table 2.3). Disturbed sites had higher total % nitrogen (natural= 0.21% ± 0.05%, disturbed = 0.25% ± 0.07%) and significantly lower phosphorus content (natural = 31.60 ppm ± 1.50, disturbed = 22.00 ppm ± 3.79). Soil pH, calcium, potassium and magnesium were not affected by disturbance type ($F_{1,6}$=6.7749, p=0.040; $F_{1,6}$=2.563, p=0.1605; $F_{1,6}$=1.255, p=0.3054; $F_{1,6}$=0.578, p=0.4758, respectively). Disturbed sites had significantly less soil moisture in both July (df=1, χ^2=95.98, p<0.001) and August (df=1, χ^2=14.32, p<0.001), having 5.1% and 2.4% less moisture, respectively, when compared to natural sites (Table 2.3).

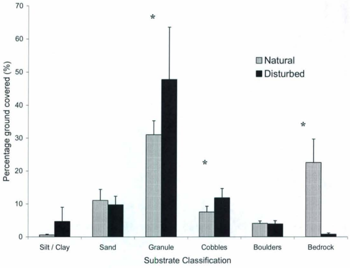

Figure 2.2 Total ground covered (mean ± SE) by visual estimation of substrate classes following Wentworth (1922), on naturally- (n=5 sites) and anthropogenically-disturbed (n=3 sites) *S. jejuna* study sites, on the limestone barrens of Newfoundland (Canada); * represents significant difference between disturbance types (nested binomial logistic regression)

Table 2.2 Physical composition of substrate (mean (SE)) (visually estimated as % cover) compared between naturally- and anthropogenically-disturbed *S. jejuna* study sites; limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n=number of plots); p is the level of significance associated with differences between disturbance types using nested binomial logistic regression.

Site	% Silt /Clay	% Sand	% Granule & Pebbles	% Cobbles	% Boulders	% Bedrock
NATURAL						
BHN-N (n=40)	0.1 (0.06)	14.6 (1.84)	15.3 (2.28)	4.2 (0.90)	3.6 (0.94)	37.8 (3.04)
BK1-N (n=47)	1.4 (0.66)	4.4 (1.84)	30.3 (3.08)	13.9 (1.53)	4.4 (0.96)	0.7 (0.64)
BK39-N (n=41)	0.4 (0.17)	22.4 (2.73)	38.9 (3.04)	8.3 (1.13)	3.2 (0.76)	10.7 (3.02)
CNA-N (n=83)	0.8 (0.09)	8.3 (1.04)	38.0 (2.75)	6.0 (0.74)	6.7 (1.48)	32.0 (3.43)
CNC-N (n=41)	0.00 (0.03)	5.7 (0.93)	32.7 (3.04)	5.3 (1.06)	2.4 (0.87)	31.6 (3.85)
Mean	**0.5 (0.26)**	**11.08 (3.32)**	**31.0 (4.26)**	**7.5 (1.73)**	**4.1 (0.74)**	**22.6 (7.14)**
DISTURBED						
BKD-D (n=24)	13.3 (2.65)	13.8 (2.22)	22.7 (2.76)	17.4 (3.53)	3.9 (1.56)	0.4 (0.42)
CND-D (n=80)	0.8 (0.18)	4.9 (0.67)	76.9 (1.44)	9.9 (0.88)	2.2 (0.72)	0.5 (0.26)
CNE-D (n=33)	0.0 (0.00)	10.5 (1.55)	43.9 (5.00)	8.3 (2.70)	5.6 (2.77)	1.5 (0.88)
Mean	**4.7 (4.31)**	**9.7 (2.60)**	**47.8 (15.78)**	**11.8 (2.81)**	**3.9 (0.99)**	**0.8 (0.35)**
P value	**0.712**	0.056	**<0.001**	**<0.001**	0.203	**<0.001**

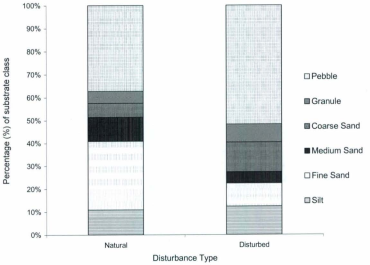

Figure 2.3 A comparison of the percentage (%) of substrate (textural analysis) in each particle size class (Wentworth 1922) on naturally- (n=5 sites) and anthropogenically-disturbed (n=3 sites); *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); n = 10, number of samples collected per site.

Table 2.3 Soil characteristics for naturally- and anthropogenically-disturbed *S. jejuna* study sites displaying mean (SE) results of chemical (n=3), textural (n=10), and moisture analysis (n=6-7); p (alpha = 0.038) indicates the level of significance associated with differences between disturbance type using nested Anova and nested binomial logistic regression;

	NATURAL						DISTURBED				
Site Characteristic	**BHN-N**	**BK1-N**	**BK39-N**	**CNA-N**	**CNC-N**	**MEAN**	**BKD-D**	**CND-D**	**CNE-D**	**MEAN**	**P**
Total Nitrogen (%)	0.29 (0.09)	0.17 (0.00)	0.16 (0.01)	0.19 (0.01)	0.24 (0.03)	0.21 (0.02)	0.15 (0.01)	0.40 (0.04)	0.21 (0.02)	0.25 (0.07)	**<0.001**
Calcium (ppm)	1725 (40.34)	2294 (257.62)	1683 (74.07)	1925 (52.04)	3147 (305.65)	2154.8 (270.55)	1925 (59.11)	11049 (6710.1)	11383 (300.89)	8119.0 (3098.50)	0.040
Magnesium (ppm)	546 (2.33)	617 (49.79)	474 (18.03)	620 (39.51)	294 (1.76)	510.20 (60.33)	607 (36.78)	314 (38.19)	373 (6.11)	431.33 (89.47)	0.476
Phosphorus (ppm)	34 (3.21)	34 (3.18)	26 (2.60)	33 (3.28)	31 (5.13)	31.60 (1.50)	29 (1.53)	21 (5.36)	16 (4.04)	22.00 (3.79)	**0.029**
Potassium (ppm)	38 (2.03)	96 (21.39)	44 (6.03)	46 (3.76)	49 (1.76)	54.60 (10.50)	62 (4.33)	70 (6.17)	81 (11.26)	71.00 (5.51)	0.305
% Silt (particle size)	7.07 (0.93)	13.79 (3.47)	11.51 (1.67)	11.60 (1.92)	10.57 (2.72)	10.91 (1.10)	18.00 (1.06)	13.38 (1.93)	5.70 (0.66)	12.36 (3.59)	0.440
% Fine sand	34.41 (3.09)	13.65 (2.00)	40.28 (3.49)	32.83 (3.77)	28.73 (4.30)	29.98 (4.48)	14.63 (1.46)	8.46 (1.13)	7.09 (0.70)	10.06 (2.32)	**<0.001**
% Medium sand	24.82 (2.34)	2.68 (0.28)	9.88 (1.10)	12.89 (1.76)	2.65 (0.39)	10.58 (4.09)	9.71 (0.90)	1.77 (0.19)	3.36 (0.49)	4.95 (2.42)	**<0.001**
% Coarse sand	9.29 (1.25)	4.69 (0.54)	4.99 (0.70)	6.59 (1.05)	4.81 (0.77)	6.07 (0.87)	17.99 (2.28)	6.23 (1.45)	14.71 (2.61)	12.98 3.50	**<0.001**
% Granule	6.39 (0.94)	5.76 (1.35)	3.57 (0.85)	4.26 (1.40)	6.02 (1.43)	5.20 (0.54)	8.99 (0.72)	6.73 (2.21)	8.08 (1.22)	7.93 (0.66)	**<0.001**
% Pebble	18.03 (5.95)	59.52 (5.65)	29.78 (5.05)	31.83 (7.12)	47.23 (6.13)	37.28 (16.20)	30.68 (3.87)	63.43 (3.71)	61.06 (4.76)	51.72 (10.54)	**<0.001**
% Soil Moisture July 3	13.65 (3.05)	14.66 (3.28)	12.34 (2.76)	17.66 (3.95)	13.55 (3.03)	14.37 (0.90)	12.31 (2.75)	7.97 (1.78)	7.55 (1.69)	9.28 (1.52)	**<0.001**
Aug 8	10.83 (4.09)	15.24 (6.22)	12.14 (4.59)	11.69 (4.42)	11.23 (4.58)	12.23 (0.78)	13.75 (5.61)	9.25 (3.49)	6.42 (2.62)	9.81 (3.70)	**<0.001**

Influence of disturbance type on vegetation

Total vegetation cover was similar on natural and disturbed sites (25.7%), though the amount of cover differed between disturbance types for the majority of functional groups (Table 2.4). Herbaceous cover (df=1, χ^2=11.22, p<0.001) was greatest on disturbed sites having a mean cover of 3.3%± 0.39% versus 2.9%± 0.61% on natural sites. Natural sites (5.2% ± 2.78%) had the greatest coverage of bryophytes, ranging from 0.1% (CNA-N) to 12.3% (BK1-N), with disturbed sites having only 1.8% ± 0.96% (df=1, χ^2=36.02, p<0.001). Bare ground was greatest on disturbed sites (78.0% ± 8.62%) when compared to natural sites (76.4% ± 6.09%) (df=1, χ^2=20.16, p<0.001). Even though exposed bedrock was, in general, more prevalent on natural sites, bare ground was higher on disturbed sites due to the large portion of gravel content. Woody plant and lichen cover was similar on both natural (woody: 17.3% ± 5.97%; lichen: 0.3% ± 0.28%) and disturbed sites (woody: 20.5% ± 9.20%; lichen: 0.1% ± 0.08%; df=1, χ^2=3.97, p=0.0463; χ^2=1.55, p=0.2138, respectively).

Natural and disturbed sites were found to have 44 and 41 vascular plant species, ranging from 18-33 and 26-28, respectively (see full listing of species in Appendix I; does not include *Carex* and *Poa* species, which accounted for less than 2% mean combined coverage in both disturbance types). Species richness, Shannon diversity index, and evenness (Table 2.5) were not affected by disturbance type ($F_{1,6}$=0.014, p=0.9074; $F_{1,6}$=0.1169, p=0.7441; $F_{1,6}$=0.4844, p=0.5123, respectively).

Table 2.4 Mean ± SE total ground area covered for naturally- and anthropogenically-disturbed *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n= number of study plots); p indicates the level of significance associated with differences between disturbance type using nested binomial logistic regression.

Site	n	Woody Cover (%)	Herbaceous Cover (%)	Byrophyte Cover (%)	Lichen Cover (%)	Bare ground Cover (%)
NATURAL						
BHN-N	40	20.4 ± 3.69	3.4 ± 0.32	1.8 ± 1.70	0.1 ± 0.12	75.3 ± 3.54
BK1-N	47	39.3 ± 8.19	5.0 ± 0.62	12.3 ± 2.60	1.4 ± 0.72	54.9 ± 4.27
BK39-N	41	11.7 ± 1.56	2.4 ± 0.21	0.2 ± 0.11	0.0 ± 0.00	83.3 ± 1.60
CNA-N	83	6.3 ± 0.74	1.6 ± 0.10	0.1 ± 0.07	0.0 ± 0.00	91.5 ± 0.76
CNC-N	41	9.1 ± 1.90	2.1 ± 0.17	11.8 ± 1.54	0.0 ± 0.00	77.2 ± 2.46
Mean		**17.3 ± 5.97**	**2.9 ± 0.61**	**5.2 ± 2.78**	**0.3 ± 0.28**	**76.4 ± 6.09**
DISTURBED						
BKD-D	24	26.5 ± 7.95	3.6 ± 1.48	3.2 ± 0.82	0.3 ± 0.21	72.1 ± 5.86
CND-D	80	2.4 ± 0.38	2.6 ± 0.15	0.0 ± 0.00	0.0 ± 0.00	95.0 ± 0.40
CNE-D	33	32.5 ± 8.76	3.8 ± 0.29	2.3 ± 0.67	0.0 ± 0.03	66.9 ± 5.05
Mean		**20.5 ± 9.20**	**3.3 ± 0.39**	**1.8 ± 0.96**	**0.1 ± 0.08**	**78.0 ± 8.62**
P value		0.046	**<0.001**	**<0.001**	0.2138	**<0.001**

Of the plant species found most were native perennials, one is considered provincially rare (*Gentianella propinqua*), one is endemic to the island of Newfoundland (*Braya fernaldii*; threatened), while only four were annuals (*Euphrasia* spp, *Gentianella propinqua*, *Lomatogonium rotatum*, *Rhinanthus minor*). Seven species were restricted to natural sites (*Antennaria alpina*, *A. eucosma*, *B.fernaldii, Dasiphora fruticosa*, *Saxifraga aizoides*, *Tofieldia glutinosa*, *Viola nephrophylla*) while 3 species were limited to disturbed sites (*Taraxacum ceratophorum, Gentianopsis nesophila, Gentianella propinqua)*. No non-native plant species were found. With the exception of a few woody species (*Dryas integrifolia, Empetrum nigrum, Juniperus horizontalis, Salix jejuna, S. vestita*), the majority of vascular plant species had less than 1% mean coverage on all sites (see Table AII.I).

Table 2.5 A comparison of species richness, Shannon diversity and Shannon evenness values for naturally- and anthropogenically-disturbed *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n=number of plots); p indicates the level of significance associated with differences between disturbance type using nested Anova

Site	Species richness (per m^2)	Shannon diversity (per m^2)	Shannon evenness (per m^2)
NATURAL			
BHN-N (n=40)	9.47	1.23	0.56
BK1-N (n=47)	11.08	1.31	0.55
BK39-N (n=41)	14.51	1.39	0.53
CNA-N (n=83)	7.07	0.84	0.43
CNC-N (n=41)	8.54	1.01	0.46
Mean	**10.13**	**1.16**	**0.51**
DISTURBED			
BKD-D (n=24)	10.79	1.14	0.48
CND-D (n=80)	9.20	1.05	0.47
CNE-D (n=33)	9.70	1.11	0.47
Mean	9.90	1.10	0.47
P Value	**0.9074**	**0.7441**	**0.5123**

Influence of disturbance on habitat across the species range

Principle components analysis indicates that anthropogenically-disturbed sites were more homogeneous in habitat structure when compared to naturally-disturbed sites (Fig 2.4). Disturbed sites generally grouped along both principle components, with the exception of a few plots with higher woody coverage at CNE-D, which were located at the edge of unmodified habitat.

Habitat of anthropogenically-disturbed sites varied according to disturbance intensity (Fig 2.4); where the organic layer had been partially or totally removed, and where the habitat was continually disturbed (e.g., ATVs, road dust), sites were characterized by higher gravel content (both % cover and textural analysis), lower soil moisture and depleted levels of phosphorus (Table 2.2 & 2.3). CND-D (intensity level 3), a site where the organic layer was completely removed, is distinguished by high gravel content, very low woody species cover, and the absence of bryophytes and lichens. In contrast, BKD-D (intensity level 1), where the organic layer was only partially removed and where evidence of frost sorting exists, fine particles are still present, allowing for the colonization of bryophytes.

Just as there is variation in the degree of anthropogenic disturbance across species range there is also variation in natural disturbance intensity (cryogenic processes) and substrate conditions (Greene 2002; Rafuse 2005). Natural substrates vary from patterned ground in the form of frost boils at BK1-N or frost stripes at BK39-N, to sites with primarily exposed bedrock (BHN-N, CNA-N, CNC-N) and no evidence of frost action (Figure 2.4).

PC1 accounted for 24% variance and represented sites with a high amount of woody, herbaceous, bryophyte and lichen cover (loadings >0.20). PC1 also represented sites with a low amount of bare ground (-0.58) and granule size particles (-0.37). PC2 accounted for 15% variance and represented sites with low bedrock cover (-0.74) and high granule content (>0.38).

Variation in substrate conditions and vegetation cover among and within natural sites may be explained along a geographical gradient, though the pattern is not true for all substrate or vegetation classes. For example, BK1-N, the most southern site, has little exposed bedrock (0.7%), while BHN-N, CNC-N, and CNA-N, the most northerly sites have much higher exposed bedrock content (31.6%–37.8%) (Table 2.2). However, geographically close sites were not always similar in vegetation cover; CNC-N had considerably more bryophyte cover (11.8%) than CNA-N (0.1%) even though these sites have similar substrate conditions and are approximately one kilometre apart.

In addition, BK1-N and CNC-N stand out among the natural sites as having high bryophyte cover, even though these sites have quite different substrate conditions. At BK1-N bryophytes grow on fine, moist sediments, whereas bryophytes grow within the crevasses of large blocks of exposed bedrock and on patches of shallow soil overlaying bedrock at CNC-N. The shattered limestone bedrock and fine sediment at BK1-N contribute to the high amount of woody cover by providing conditions for root anchoring.

What habitat characteristics influence the abundance of S. jejuna?

S. jejuna was more abundant on disturbed sites (natural= 1.3%±0.18%; disturbed=2.3%±0.28%; df=1, χ^2=43.44, p<0.001), ranging from 1.1% (CND-D) to 3.9% (CNE-D), and having significant among site variation (df=6, χ^2=162.45, p<0.001). *S. jejuna* ranged from 0.6% (CNC-N) to 2.9% (BK1-N) on natural sites. Regression analysis on pooled data (all sites) shows that among all measured substrate and vegetation cover classes, three were most important for the coverage of *S. jejuna*; namely, the cover of woody plants (excluding target species) (df=1, χ^2=393.67, p<0.001), bryophytes (df=1, χ^2=91.87, p<0.001), and the percentage of bare ground (df=1, χ^2=6.80, p=0.009).

S. jejuna has greatest coverage when woody plant cover is less than 50%, when bryophyte cover is less than 20%, and when bare ground cover exceeds 60%. Spearman's rank correlation analysis on pooled data, using percent cover values, indicates *S. jejuna* is positively correlated with *Plantago maritima* (r=0.354, p<0.001), *Salix reticulata* (r=0.242, p<0.001), and *Saxifrage oppositifolia* (r=0.149, p=0.003). *S. jejuna* occurs with these species on all sites and there is no pattern with disturbance type. *S. jejuna* is negatively correlated with *Dryas integrifolia* (r=-0.238, p<0.001), *Juniperus horizontalis* (r=-0.242, p<0.001), *Pinguicula vulgaris* (r=-0.224, p<0.001), and *Empetrum nigrum* (r = -0.155, p= 0.002). *S. jejuna* is particularly low in abundance (<1% cover) when plots were high in coverage of three woody species; when *D. integrifolia* is greater than 10%, *J. horizontalis* is greater than 15%, and when *E. nigrum* is greater than 20%. This relationship occurred on 60 to 80% of all sites and was not dependent on disturbance type.

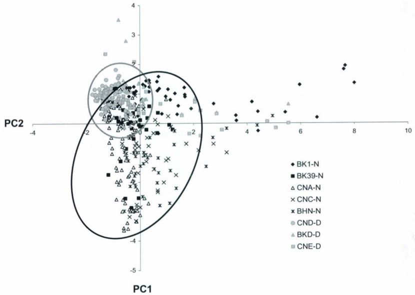

Figure 2.4 Scatterplot of first two principle components for naturally- and anthropogenically-disturbed populations of *Salix jejuna,* on the limestone barrens of Newfoundland (Canada). The large circles (Natural=black, Disturbed=grey) encompass the majority of plots within each disturbance type. Each point on the scatterplot represents a study plot, coded by site and disturbance type (Natural= black, Disturbed= grey). Outliers are plots located along site boundaries (e.g., BK1-N and CNE-D) with significantly greater woody species cover. PC1 accounted for 24% variance and represented sites with a high amount of woody, herbaceous, bryophyte and lichen cover (loadings >0.20) and a low amount of bare ground (-0.58) and granule size particles (-0.37). PC2 accounted for 15% variance and represented sites with low bedrock cover (-0.74) and high granule content (>0.38).

2.4 DISCUSSION

Study results show distinct differences in substrate conditions and vegetation community structure between naturally- and anthropogenically-disturbed limestone barrens habitat, throughout the narrow range of the endemic, endangered *Salix jejuna*. Anthropogenically-disturbed sites have coarser substrate (30% more gravel) with less fine grained sands, less exposed bedrock, decreased soil moisture, increased nitrogen content, reduced phosphorus content, as well as increased herbaceous and reduced bryophyte cover. If anthropogenically-disturbed sites are to be used as recovery habitat for endangered limestone species, they will need to be restored to promote natural ecosystem processes, natural vegetation community structure, and to reflect the heterogeneity of natural habitat.

Effects of disturbance on substrate conditions and vegetation

The habitat of most species is heterogeneous on many scales due to natural disturbances and impacts of human activities (Lord and Norton 1990). However, it appears that human disturbance on the limestone barrens creates homogeneous habitat which lacks fine sediments and pronounced substrate sorting (e.g., frost boils or stripes). Natural sites, in contrast, display much variation in substrate and vegetation cover across species range, as well as natural disturbance patterns. Studies on the limestone pavement alvars of Ontario (Canada) also show spatial heterogeneity in vegetation cover (Stark et al. 2003) and environmental factors such as soil depth, microsite composition, and elevation (Lundholm and Larson 2003). Vegetation cover (Stark et al. 2003) and species richness (Lundholm and Larson 2003) were positively correlated with soil depth. Microsite composition heterogeneity also played an important role in species richness (Lundholm and Larson 2003). Variation in species richness within natural sites suggests that large-scale spatial variability in environmental factors may occur across species range and should be further studied to understand their role in the growth of *S. jejuna* and in the maintenance of this unique limestone habitat.

In a similar study, Greene (2002) found comparable results in substrate conditions on disturbed sites when studying the habitat requirements of two *Braya* species, also endemic to the limestone barrens of Newfoundland. He noted that anthropogenically-disturbed sites experienced less natural disturbance and had at least 50% more gravel content than natural sites. Previous to this, Noel (2000) demonstrated that *Braya* on human-modified substrates experienced high recruitment but low persistence, while the opposite was true for naturally-disturbed substrates. This work also indicates a change in the target species growth (e.g., *S. jejuna* was found to have greater coverage on disturbed sites) while previous research noted changes to the species life history traits on disturbed sites (Chapter 3). For example, in a companion study, it was noted that the ability of plants to reproduce clonally through layering was reduced on disturbed substrates (Chapter 3). The lack of fine particle sized substrates on disturbed sites is thought to be the main limitation to clonal growth as adventitious roots produced on lateral branches cannot establish in coarse sediments. A reduction in sand content was also observed on abandoned limestone quarries in Ontario (Tomlinson et al 2008) though no related studies were found which examined the effects of disturbance on native alvar plant species reproduction.

Habitat changes in anthropogenically-disturbed substrate, such as the removal of fine grained particles, resulted in a reduction in soil moisture (Driscoll 2006), by decreasing the retention properties of the soil matrix (McKendrick 1997). Studies under similar arctic-like climate regimes have shown that a reduction in soil moisture can affect the recovery potential of disturbed sites (Babbs and Bliss 1974; Bishop and Chapin 1989). In their review of disturbance effects in the high Arctic, Forbes et al. (2001) noted that natural regeneration was very slow on dry disturbed sites and recovery was decreased on dry sites that experienced even low intensity disturbance (e.g., light trampling, or in this case ATV traffic). These studies suggest that without site-specific restoration, disturbed areas within the limestone barrens may have a very slow natural recovery rate, especially considering that natural cryogenic processes are limited on disturbed sites; processes by which many arctic-alpine plants depend for upon successful establishment by seed (Noel 2000; Sutton et al. 2006).

Natural recovery of disturbed sites can sometimes lead to changes in species composition (Sumina 1994); however, as is common in most disturbed arctic-tundra communities, there was no major shift in the vascular plant assemblage on disturbed sites, and no non-native species were found (Babb and Bliss 1974; Ebersole 1987; Kevan et al. 1995; Forbes and Jeffries 1999), even on sites with close proximity to frequently travelled roadways. This contrasts the findings of species composition for abandoned limestone quarries in Ontario; vegetation consisted of 40% non-native exotic species (Tomlinson et al. 2008), in comparison to 7% in undisturbed alvar communities (Schaefer and Larson 1997). The arctic-like climate and cool onshore winds distinguish the flora of the limestone barrens from the native alvar flora of Ontario and inhibit the introduction of non-native species (Catling and Brownell 1995).

Though revegetation of disturbed sites on the limestone barrens is primarily by native vegetation, it remains unclear whether these native species have established by seed from adjacent naturally-disturbed communities or from seeds that remained in the disturbed soils. A companion study (Chapter 3) showed that disturbed sites have a larger proportion of young *S. jejuna* plants (<10 years), comprising of 53-63% of the studied populations. Moreover, populations inhabiting natural sites had a larger proportion of individuals over the age of 21; 17% on natural sites versus 4% on disturbed sites (Chapter 3). These data suggest that *S. jejuna* established subsequent to the disturbance event. This is also likely true for the other five prostrate *Salix* (*S. calcicola, S. glauca, S. reticulata, S. uva-ursi, S. vestita*) species which were found on disturbed sites and accounted for a large portion of woody cover. *Salix* species are known to be important colonizers of disturbed areas in tundra communities, often having high seed production and viability (Bliss 1958; Sumina 1994). This demonstrates that *S. jejuna* and other dominant *Salix* species play an important role in the primary succession of disturbed sites.

The recovery of disturbed sites can be inhibited by the continual disturbance of off-road vehicle use (e.g., ATVs) (Rafuse 2005), which was commonly observed during fieldwork. And, unfortunately, the rocky nature of the limestone barrens leads to the common misconception that these areas can withstand the pressures of continued off-road vehicle use. Many authors have examined the response and resilience of arctic or alpine plant communities to anthropogenic disturbances such as pedestrian trampling. In arctic Alaska (US), Monz (2002) noted a reduction in plant cover of greater than 50% immediately after trampling. Cole (1995) found that woody shrubs were moderately resilient to trampling; however Forbes (1992) demonstrated that few dwarf woody shrubs survived light trampling. In an alpine area in Italy, Rossi et al. (2006) confirmed that *Salix herbacea* was very susceptible to trampling damage, which is consistent with Rafuse (2005) who noted direct physical damage to *S. jejuna* by off-road vehicles, on the limestone barrens of Newfoundland. In a long term demographic study, Maschinski et al. (1997) showed that human trampling caused high mortality rates and negatively impacted the time to reproduction in seedlings of the endangered limestone perennial *Astragalus cremnophylax var cremnophylax*. After restricting public access to the endangered plant, populations rebounded and viability modeling indicated a stabilized population. These studies, and others, suggest that in order to ensure the long term persistence of *S. jejuna* all off-road vehicle use should be prohibited on the limestone barrens to protect its reproductive potential and critical habitat.

Recommendations for recovery and restoration

Globally, the botanically and geologically rich habitats of limestone pavements (barrens) are threatened due to quarrying, residential development, farmland conversion and horticultural use (Catling and Brownell 1995; Reschke et al. 1999; Goldie 1993; Bennett et al. 1995). Preservation of natural limestone habitat is essential as only 3% of the limestone pavement remains intact in some countries (Anon 2001).

The endemic *Salix jejuna* is associated with the restricted limestone barrens habitat of Newfoundland. Persistence in this unique environment relies on the ability to adapt to the challenging conditions presented by an arctic-like climate (e.g., short growing season, temperature fluctuations, cryogenic substrate processes), as well as a nutrient poor, moisture depleted limestone substrate, and more recently, the pressures of human disturbance. This research has demonstrated that *S. jejuna* can establish under all of these stressors and plays a critical role in the natural revegetation of disturbed habitat within this globally rare ecosystem.

However, this research suggests that the long term stability of *S. jejuna* is compromised by human disturbance through road construction, quarrying, and off-road vehicle use. Substrate changes have been shown to alter reproduction through the removal of fine grained particles on disturbed sites. Removal of fine sediments decreases the retention properties of the soil matrix, likely leading to a depletion of important macro nutrients such as phosphorus (Kevan et al. 1995).

Off-road vehicle use has long term consequences to this fragile, imperilled habitat and to its endemic, rare plants. Rafuse (2005) demonstrated that off-road vehicle use on the limestone barrens was dependent upon the substrate conditions. For example, sites with rounded rocks and little soil content, as seen at the most severely disturbed site in this study, were moved easily and caused direct damage to endemic plants. Sites with thicker soil content, as seen at the majority of *S. jejuna* natural sites, hold angular rocks upright which are more resistant to movement by vehicle traffic, hence, less damage to individual plants occurs. The research presented herein suggests that even severely disturbed sites are negatively affected by off-road vehicle use and that all off-road vehicle use should be restricted on the limestone barrens.

Removal of the pressures associated with off-road vehicle traffic may not be sufficient for the complete recovery of *S. jejuna* and of disturbed limestone barrens substrate in general. Due to the large portion of disturbed habitat within *S. jejuna*'s limited range, active restoration of disturbed sites may be needed to meet the optimal habitat requirements of *S. jejuna* and to ensure population persistence. Additionally, long term demographic monitoring of populations (Chapter 3) may indicate that the introduction of *S. jejuna* to unoccupied undisturbed sites is necessary for long term species persistence. Preliminary field trials indicate that the establishment of cuttings *in situ* may be an effective method of reintroduction (Driscoll unpublished data).

Restoration of disturbed habitat may require the addition of fine textured soils to coarse material as a means of improving water retention and nutrient binding capacity, as suggested for disturbed arctic communities (McKendrick 1997). The addition of sand-sized particles has also been suggested as a restoration strategy for improving revegetation on abandoned limestone quarries (Tomlinson et al. 2008) or other areas where accumulations of substrate have been removed (Stark et al. 2004).

If restoration is deemed necessary, management should also endeavour to reflect the heterogeneity of adjacent natural communities, also keeping in mind the species preferences highlighted in this paper (e.g., *S. jejuna*'s positive association with *S. reticulata, Plantago maritima* and *Saxifrage oppositifolia*). Management of this rare species may also require the maintenance of open habitats to reduce competition by other woody species such as *Juniperus horizontalis, Dryas integrifolia*, or *Empetrum nigrum*, which interestingly, has been shown to have phytotoxic properties (Nilsson 1994). This may require the removal or "trimming" of individual plants on selected sites, though scientifically defensible experimental research should be conducted to determine the effectiveness of this, and other proposed recovery solutions, including substrate manipulations.

In summary, this work provides valuable information to conservation managers and could effectively be used: i) to aid in the development of effective recovery documents; ii) as a scientifically defensible template for active restoration of disturbed limestone barrens habitat and a means of restoration evaluation; iii) for accurate delineation of critical habitat; iv) for identification of suitable reintroduction sites if required; and v) for the evaluation of areas best suited for ecotourism activities (e.g., walking paths), should they be developed.

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2.5 REFERENCES

Allen T (1990) Particle Size Measurement Fifth Ed, Chapman and Hall, New York, USA

Alonso A, Dallmeier F, Granek E, Raven P (2001) Biodiversity: connecting with the tapestry of life. Smithsonian Institution/Monitoring and assessment of Biodiversity Program and President's Committee of Advisors on Science and Technology, Washington, DC.

Anions MFE (2001) COSEWIC status report on Barrens Willow, *Salix jejuna*. Committee on the Status of Endangered Wildlife in Canada. 24 pp. (Unpublished report)

Anon (2001) Biodiversity – Saving limestone pavement. Mining, Quarrying and Recycling 30:28-29

Auerbach NA, Walker MD, Walker DA (1997) Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. Ecological Applications 7:218-235

Babb TA, Bliss LC (1974) Effects of physical disturbance on High Arctic vegetation in the Queen Elizabeth Islands. Journal of Applied Ecology 11:549-562

Banfield C (1983) Climate In: South RG (ed) Biogeography and Ecology of the Island of Newfoundland, Junk Publishers, Boston

Belcher JW, Keddy PA, Catling PM (1992) Alvar vegetation in Canada: a multivariate description at two scales. Canadian Journal of Botany 70:1279-1291

Bennett AF, Bennett MR, Doyle P (1995) Paving the way for conservation? Geology Today May-June 98-100

Bishop SC, Chapin SF III (1989) Establishment of *Salix alaxensis* on a gravel pad in arctic Alaska. The Journal of Applied Ecology 26:575-583

Bliss LC (1958) Seed germination in arctic and alpine species. Arctic 11:180-188

Bouchard A, Hay S, Brouillet L, Jean M, Saucier I (1991) The rare vascular plants of the Island of Newfoundland. Syllogeus No. 65.

Brooks TM, Mittermeier RA, Mittermeier CG, Da Fonseca GAB, Rylands AB, Konstant WR, Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylor C (2002) Habitat loss and extinction in the hotspots of biodiversity. Conservation Biology 16:909-923

Catling PM (1995) The extent of confinement of vascular plants in southern Ontario. Canadian Field Naturalist 109:172-181

Catling PM, Brownell VR (1995) A review of the alvars of the Great Lakes region: distribution, floristic composition, biogeography and protection. Canadian Field Naturalist 109:143-171

Chapin FS, Shaver GR (1981) Changes in soil properties and vegetation following disturbance of Alaskan Arctic Tundra. Journal of Applied Ecology 18:605-617

Cole DN (1995) Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. The Journal of Applied Ecology 32:203-214

Djan-Chékar N, Hermanutz L, Ballam D, Bell T, Brazil J, Mann H, Maunder J, Meades SJ, Nicholls W, Soper L, Yetman G (2003) Recovery strategy for the Barrens Willow (*Salix jejuna* Fernald). Inland Fish and Wildlife Division, Government of Newfoundland and Labrador, Corner Brook, Canada 11 pp.

Donato E (2005) Climatology of the Limestone Barrens, Northern Peninsula, Newfoundland: Implications for rare plant phenology and distribution. M.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Driscoll J (2006) *Ex situ* conservation protocols for the rare plants *Braya longii* (endangered), *Braya fernaldii* (threatened) (Brassicaceae) and *Salix jejuna* (endangered) (Salicaceae), endemic to the Limestone Barrens of Newfoundland. M.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Ebersole JJ (1987) Short-term vegetation recovery at an Alaskan arctic coastal plain site. Arctic and Alpine Research 19:442-450

Fiedler PL, Ahouse JJ (1992) Hierarchies of cause: toward an understanding of rarity in vascular plant species. In: Fiedler PL and Jain SK (eds) Conservation biology: The theory and practice of nature conservation, preservation and management, Chapman & Hall, New York, USA

Forbes BC (1992) Tundra disturbance studies. II. Plant growth forms of human-disturbed ground in the Canadian Far North. Musk-Ox 49:46-55

Forbes BC, Jefferies RL (1999) Revegetation of disturbed arctic sites: constraints and applications. Biological Conservation 88:15-24

Forbes BC, Ebersole JJ, Strandberg B (2001) Anthropogenic disturbance and patch dynamics in circumpolar arctic ecosystems. Conservation Biology 5:954-969

Grant DR (1992) Quaternary Geology of St. Anthony- Blanc Sablon Area, Newfoundland and Quebec. Geological Survey of Canada, Memoir 427

Greene S (2002) Substrate characteristics of *Braya* habitat on the limestone barrens, Great Northern Peninsula, Newfoundland. B.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Goldie HS (1993) The legal protection of limestone pavements in Great Britain. Environmental Geology 21:160-166

Hermanutz LA, Mann H, Anions MFE, Ballam D, Bell T, Brazil J, Djan-Chékar N, Gibbons G, Maunder J, Meades SJ, Nicholls W, Smith N, Yetman G. (2002). National Recovery Plan for *Braya longii* and *B. fernaldii*. National Recovery Plan No. 23. Recovery of Nationally Endangered Wildlife (RENEW), Ottawa, Ontario, Canada.

Hermanutz, L., S. Squires, and D. Pelley (2009) Limestone Barrens Research Report. Report to the Wildlife Division, Government of Newfoundland and Labrador, Corner Brook, Newfoundland, Canada.

Hobbs RJ, Norton DA (1996) Towards a conceptual framework for restoration ecology. Restoration Ecology 4:93-110

Kerr JT, Deguise I (2004) Habitat loss and the limits to endangered species recovery. Ecology Letters 7:1163 - 1169

Kevan PG, Forbes BC, Kevan SM, Behan-Pelletier V (1995) Vehicle tracks on high Arctic tundra: their effects on the soil, vegetation, and soil arthropods. Journal of Applied Ecology 32:655-667

Lewis K (2004) How important is the statistical approach for analyzing categorical data? A critique using artificial nests. Oikos 104:305-315

Little RC, Stroup WW, Freund RJ (2002) SAS for Linear Models, Fourth Edition, SAS Institute Inc, Cary, NC, USA

Lord JM, Norton DA (1990) Scale and the spatial concept of fragmentation. Conservation Biology 4:197-202

Lundholm JT, Larson DW (2003) Relationships between spatial environmental heterogeneity and plant species diversity on a limestone pavement. Ecography 26:715-722

Magurran AE (1988) Ecological diversity and measurement. Princeton University Press, Princeton, USA

Maschinski J, Frye R, Rutman S (1997) Demography and population viability of an endangered plant species before and after protection from trampling. Conservation Biology 11:990-999

Maschinski J, Baggs JE, Sacchi CF (2004) Seedling recruitment and survival of an endangered limestone endemic in its natural habitat and experimental reintroduction sites. American Journal of Botany 91: 689-698

McIntyre S, Lavorel S (1994) Predicting richness of native, rare, and exotic plants in response to habitat and disturbance variables across a variegated landscape. Conservation Biology 8:521-531

McKendrick JD (1997) Long term recovery in northern Alaska. In: Crawford, RMM (Ed), Disturbance and Recovery in Arctic Lands: an Ecological Perspective. Kluwer Academic, Dordrecht, The Netherlands, pp. 503-518.

Miller JR, Hobbs RJ (2007) Habitat restoration – do we know what we're doing? Restoration Ecology 15:382-390

Monz CA (2002) The response of two arctic tundra plant communities to human trampling disturbance. Journal of Environmental Management 64:207-217

Nilsson MC (1994) Separation of allelopathy and resource competition by the Boreal Dwarf Shrub *Empetrum nigrum ssp. hermaphroditum* Hagerup. Oecologia 98: 1-7

Noel L (2000) The effect of disturbance on the seedling recruitment and persistence of *Braya longii* and *Braya fernaldii*. Honours thesis. Memorial University, St. John's, Newfoundland, Canada.

Parsons K, Hermanutz L (2006) Conservation of rare, endemic braya species (Brassicaceae): Breeding system variation, potential hybridization, and human disturbance. Biological Conservation 128:201-214

Rafuse G (2005) The impact of off-road vehicles on the Limestone Barrens habitat and resident plants endemic to the Great Northern Peninsula, Newfoundland, Canada. Honours Thesis. Memorial University, St. John's, Newfoundland, Canada

Reschke C, Reid R, Jones J, Feeney T, Potter H (1999) Conserving Great Lakes alvars. The Nature Conservancy, Chicago, IL, USA

Rossi G, Parolo G, Zonta LA, Crawford JA, Leonard A (2006) *Salix herbacea* L. fragmented small population in the N-Apennines (Italy): response to human trampling disturbance. Biodiversity and Conservation 15:3881-3893

SAS Institute Inc. (1996) SAS/STAT user's guide, release 6.12 ed. SAS Institute Inc., Cary, North Carolina, USA

Schaefer CA, Larson DW (1997) Vegetation, environmental characteristics and ideas on the maintenance of alvars on the Bruce Peninsula, Canada. Journal of Vegetation Science 8:797–810

Society of Ecological Restoration International Science and Policy Working Group (2004) The SER International Primer on Ecological Restoration (available at www.ser.org)

Species at Risk Act. (2003). Species at Risk Act, Statutes of Canada. Canada Gazette. Queen's Printer for Canada, Ottawa, Ontario.

Squires S (2010) Insect pests and pathogens compromise the persistence of two endemic and rare Braya (Brassicaceae). PhD Thesis, Memorial University, St. John's, Newfoundland, Canada.

Stark KE, Lundholm HT, Larson DW (2003) Relationships between seed banks and spatial herterogeneity of North American alvar vegetation. Journal of Vegetation Science 14: 205-212

Stark KE, Lundholm JT, Larson DW (2004) Arrested development of soils on alvars of Ontario, Canada: Implications for conservation and restoration. Natural Areas Journal 24:95-100

Sumina OI (1994) Plant communities on anthropogenically disturbed sites on the Chukotka Peninsula, Russia. Journal of Vegetation Science 5:885-896

Sutton JT, Hermanutz L, Jacobs JD (2006) Are frost boils important for the recruitment of Arctic-Alpine plants? Arctic, Antarctic & Alpine Research 38:273-275

Tomlinson S, Matthes U, Richardson PJ, Larson DW (2008) The ecological equivalence of quarry floors to alvars. Applied Vegetation Science 11:73-82

Wentworth CK (1922) A scale of grade and class terms for clastic sediments. Journal of Geology 30:377-392

3.0 ANTHROPOGENIC DISTURBANCE ALTERS THE LIFE HISTORY TRAITS OF THE LIMESTONE ENDEMIC, *SALIX JEJUNA*

3.1 INTRODUCTION

Anthropogenic disturbance has been shown to alter the predominant life form in plant communities (McIntyre et al. 1995), decrease population growth rate (Ureta & Martorell 2009), and increase the likelihood of hybridization in natural populations of rare plants (Lamont et al. 2003; Parsons and Hermanutz 2006), having direct implications on long term population persistence (Maschinski et al. 1997). Populations of endemic rare plant species are especially vulnerable to anthropogenic change because of their unique habitat, limited distributions, and requirement for specific disturbance regimes (Fielder and Ahouse 1992; Maschinski et al. 2004). Due to the restricted nature of rare endemic plant species (Kruckeberg and Rabinowitz 1985), and the occurrence of anthropogenic disturbance worldwide (Hoekstra et al. 2005), anthropogenically-disturbed areas may be required for use as recovery habitat. However, recovery planners must first determine whether disturbed habitats are capable of supporting long term self-sustaining rare plant populations by examining the species response to disturbance.

The effects of disturbance on rare plant populations inhabiting anthropogenically-disturbed habitats have been examined in a variety of habitats (Pavlovic 1994; Maschinski et al. 1997; Walck et al. 1999; Lamont et al. 2003; Martorell & Peters 2005; Parsons and Hermanutz 2006; Martorell 2007; Ureta and Martorell 2009), however, few studies have addressed the response of woody species to human disturbance (Tolvanen et al. 2002; Morris et al. 2004; Rossi et al. 2006). Furthermore, although it is estimated that at least 60 rare plant species occupy both naturally- and anthropogenically-disturbed habitats worldwide (Pavlovic 1994), the comparative reproductive biology or demography of rare plant populations between disturbance types has been minimally examined (Noel 2000; Quintana-Ascencio et al. 2007; Squires 2010).

The northern limestone barrens of Newfoundland (Canada) are considered a national hot spot for plant diversity, supporting three SARA listed endemics (Species at Risk Act 2003) and 114 of the province's 271 rare plant species (Bouchard et al. 1991). Over the last several decades, anthropogenic activities (e.g., quarry, road construction, off-road vehicle use) have degraded much of this globally rare habitat (Hermanutz et al. 2002; Djan-Chékar et al. 2003) and have altered the natural soil disturbances (via frost activity) (Greene 2002; Rafuse 2005; Chapter 2) on which many arctic-alpine plants rely upon for regeneration (Noel 2000; Sutton et al. 2006). Noel (2000) noted that anthropogenically-disturbed populations of two limestone endemics, *Braya longii* (endangered) and *B. fernaldii* (threatened), displayed marked differences in their life history traits in comparison to naturally-disturbed populations (Species at Risk Act 2003). Plants on naturally-disturbed soils were smaller and had a patchy distribution, whereas, plants on anthropogenically-disturbed soils were larger, produced more seeds, had a shorter life span (Noel 2000), and were more at risk to insects and pathogens (Squires 2010). In another study, Rafuse (2005) demonstrated that off-road vehicle use on the limestone barrens causes direct damage to native endemic plants and produces substrate compaction, which alters the micro-habitats initiated by frost activity.

A large portion of the habitat of the endangered (Species at Risk Act 2003), limestone endemic, *Salix jejuna* (Barrens willow) has also been altered or destroyed through limestone quarrying and road development (Anions 2000), and is continually disturbed due to off-road vehicle use (Rafuse 2005). Previous research on this species has focused on developing techniques for *ex situ* conservation (Driscoll 2006) with less attention paid to *in situ* species conservation. To assess the potential use of anthropogenically-disturbed areas as recovery habitat for *S. jejuna*, conservation management requires a better understanding of the species key life history parameters (longevity, reproduction) within both naturally- and anthropogenically-disturbed populations. Understanding demographic parameters and identifying disturbance effects have been outlined as recovery actions in the *S. jejuna* Recovery Strategy (Djan-Chékar et al. 2003).

Several aspects of *Salix* demography in natural populations have been studied including sex ratio (Crawford and Balfour 1983; Shafroth et al. 1994; Alstrom-Rapaport et al. 1997; Jones et al. 1999; Predavec and Danell 2001; Ueno et al. 2007), population structure (Lascoux et al.1996), seed dispersal (Densmore & Zasada 1983), seedling establishment (McLeod and McPherson 1973; Alliende and Harper 1989; Bishop and Chapin 1989; Niiyama 1990; Sacchi and Price 1992; Douglas 1994; Barsoum 2002; Gage and Cooper 2005; Yan et al.

2007), and productivity (Sampson and Jones 1977), as well as the response of *Salix* populations to both natural- (Douhovnikoff et al. 2005) and anthropogenic-disturbance (Auerbach et al. 1997; Rossi et al. 2006). Few studies, however, have examined endangered or endemic *Salix* species (but see Terzioğlu et al. 2007), unless the principle focus was to determine genetic variation (Purdy et al. 1994; Purdy and Bayer 1995; Kikuchi et al. 2005). Even fewer ecological studies have been conducted on dwarf, prostrate *Salix* species (e.g., Douglas 1987; Hakkarainen et al. 2005; Bret-Harte et al. 2002; Tolvanen et al. 2002; Reisch et al. 2007; Pakeman et al. 2008), though the life history traits of prostrate *Salix* species, inhabiting similar arctic-alpine conditions have been described. Most have been described as reproducing through an underground horizontal root or rhizome system; *S. polaris* (Douglas et al. 1997); *S. setchelliana* (Douglas 1987; 1989; 1994); and *S. herbacea* (Wijk 1986a; Beerling 1998; Stamati et al. 2007). *S. herbacea* is also known to produce adventitious roots on rhizomes, buried shoots and newly developed lateral branches (Wijk 1986b). In these harsh arctic-alpine conditions, vegetative propagation is thought to be more important than sexual reproduction (Grime 1979). In addition, although *S. jejuna* recruitment is seed limited, asexual reproduction is limited by anthropogenic disturbance; therefore, disturbance could potentially alter the natural demography of this endangered, endemic species.

This study aimed to examine the relative importance of sexual and asexual reproduction of *S. jejuna* in naturally- and anthropogenically-disturbed habitats, throughout the species range. To do this the following questions were addressed:

(i) are populations regenerating sexually? To answer this seed productivity, seed viability, natural recruitment, seed addition experiments, seed rain and population structure were examined; (ii) are populations regenerating through vegetative means? To this end, over 80% of individuals in each population were surveyed, evidence of clonal growth was recorded and excavations to investigate interconnectivity were performed; and (iii) do naturally-disturbed populations differ from anthropogenically-disturbed populations? and, if so, (iv) what effect does disturbance intensity have on anthropogenic populations? This research will contribute to science based species recovery by providing information to assess whether anthropogenically-disturbed populations require disturbance-specific or site-specific *in situ* conservation approaches.

3.2 METHODS

Study sites

Research was conducted on the limestone barrens of the Great Northern Peninsula on the island of Newfoundland (Canada), located within the Strait of Belle Isle ecoregion. The limestone barrens are characterized by a cool, wet, and windy climate that supports tundra-like vegetation (Banfield 1983; Donato 2005). This area harbours many rare plants including the endemic *Salix jejuna* (Barrens willow), two endemic *Braya* species (*Braya longii, B. fernaldii*) (Hermanutz et al. 2002), and other provincially listed species. Populations of *S. jejuna* are patchily distributed between Cape Norman in the north, and Watt's Point Ecological Reserve at the southern end of its distribution (Djan-Chékar et al. 2003;

http://www.env.gov.nl.ca/parks), and are predominately coastal, occurring on average within 100 metres of the coast of the Strait of Belle Isle.

In the past, much of the limestone barrens habitat was disturbed during the process of road construction and limestone quarrying; in the last approximately 10 years, off-road vehicles such as ATVs have caused considerable habitat degradation. To investigate the effects of anthropogenic disturbance, eight study sites across the entire species range were identified in both naturally-disturbed substrates (undisturbed by human activity though naturally-disturbed via frost activity) (N=5) and anthropogenically-disturbed substrates (N=3), referred to as "disturbed" (Table 3.1). The selected sites represent populations throughout the entire range of the species as well as populations of *S. jejuna* that were sufficiently large and dense to obtain an appropriate sample size. All sites were classified visually according to disturbance intensity (amount of anthropogenic disturbance; Rafuse 2005) on the basis of physical evidence at the time of sampling. Physical evidence included degree of soil compaction (visual estimation), amount of vehicle damage (number and depth of tracks), and proximity to continual disturbance source (e.g., road). Disturbance intensity was classified on an ordinal scale from 0 to 3 where 0= no indications of anthropogenic disturbance, 1 = low, 2= moderate, and 3= severe, following the protocol of McIntyre and Lavorel (1994).

Study species

Salix jejuna (Fernald L.) is a prostrate shrub with shoots typically reaching 1 cm in height to a maximum of 2 cm. It has short petioles and oblong to elliptic shaped leaves (Fernald 1950), with variation in leaf and plant morphology throughout its range (Appendix V). It is a deciduous, dioecious plant producing on average 13 male and female catkins per year (Driscoll, unpublished data). Male catkins are produced in early-June and begin to release pollen by the 3-4th week of June. Female catkins develop later in the growing season, being fertilized in late June and releasing seed by the 3-4th week of July (Driscoll 2006). Seeds of *S. jejuna* are very small and are dispersed readily by wind, as is common for *Salix* species (Argus 1965). Though seed weight was not measured in the present study, the dry mass of seeds was determined to be from 0.38 mg (*S. subfragilis*) to 0.23 mg (*S. rorida*) in two *Salix* species (Niiyama 1990). On the limestone barrens, *S. jejuna* is a dominant woody component, occurring with other *Salix* species such as *S. calcicola*, *S. glauca*, *S. reticulata*, and *S. uva-ursi*, and may hybridize with these congeners (Djan-Chékar et al. 2003).

Table 3.1 *Salix jejuna* study site information indicating disturbance type (N=natural, D=anthropogenic) and intensity of anthropogenic disturbance (0= none, 1= low, 2= moderate, 3= severe), on the limestone barrens of Newfoundland (Canada). Sites are listed from most southerly to most northerly; see methods for details on sampling

Site Name	Description of Disturbance	Disturbance Intensity	Density of adult *S. jejuna* plants (m^2)	Site Area (m^2)
BKD-D	Organic layer still removed, some evidence of patterned ground	1	4.2	265
BK1-N	Frost boils present; naturally shattered limestone; highly wind eroded	0	11.0	740
BK39-N	Frost stripes present; Highly wind eroded	0	45.0	670
BHN-N	Largely exposed bedrock; highly wind eroded; most coastal site	0	3.5	945
CND-D	Organic layer completely removed, rounded coarse sediment, vehicle tracks, continual exposure to vehicle dust	3	2.2	920
CNC-N	Largely exposed bedrock; Low wind erosion	0	5.7	330
CNA-N	Largely exposed bedrock; Low wind erosion	0	3.1	450
CNE-D	Organic layer partially removed, vehicle tracks, rounded coarse sediment; continual exposure to vehicle dust	2	18.3	280

Field Sampling

Demographic census

In June-July, 2006, on each site, 6 to 7 belt transects (20-30 m in length) on each site were situated perpendicular to the coast of the Strait of Belle Isle. To ensure representative sampling across the entire study area, plots (1m^2) were randomly selected and temporarily established within each belt transect. The number of plots varied among sites depending upon the total site area, density of adult plants and site homogeneity (Table 3.1). Site area was easily determined with a measuring tape as habitat occupied by *S. jejuna* was clearly distinguishable from local vegetation. Density of plants was later measured by dividing the total number of plants surveyed on each site by the number of plots surveyed on each site. Plots (N=16 – 70) were closely examined for the presence of seedlings, juveniles, vegetative adults and reproductive adults. In this study "seedlings" were considered to be < 5 mm in height with only one or no leaf scars. Plants were considered to be "juveniles" if height > 5 mm with 2-4 leaf scars, had some internode elongation and 1-2 sets of true leaves. Adult plants have more than 2 sets of true leaves, greater than 4 leaf scars and typically have multiple branching. Differentiation between seedlings of *S. uva ursi* and *S. jejuna* was difficult; therefore all *Salix* seedlings found were considered the study species (Woods and Cooper 2005). This assumption was possible as *S. jejuna* had greater ground coverage than *S. uva ursi* on all sites, with the exception of BHN-N (Chapter 2).

Determination of sex ratio

Sex is a stable character in this species. Sex ratio was determined on all sites in 2007 on two separate sampling dates due to the differential development time of male and female catkins. Established belt transects were surveyed in early-June

2007 for the presence of male catkins and were revisited in early-July 2007 for the presence of female catkins.

Fruit and Seed Production

In 2006, the number of catkins on every female plant (N = 9 - 59) encountered in the study plots was counted. In late July 2006, at the beginning of peak seed release mature catkins (N = 10-30) were randomly sampled from individuals on 7 of 8 sites. Following guidelines from the Royal Botanical Gardens, Kew (2006), less than 20% of seed produced per site was collected; with one site (BK39-N) not producing sufficient catkins to allow collection. Seeds were used in germination tests and seed addition experiments; however insufficient data were collected to allow for determination of seed production per adult. Therefore, in 2007, further catkins were collected (N=10-30) at the same phenological stage as in 2006, on 6 of 8 sites following the same procedure. In 2007, 2 sites (BK39-N and CNC-N) did not produce enough seed to allow for seed collection.

For each catkin, the total number of ovaries (fruit) was counted and random selections of 3-5 ovaries (30% of total ovaries) were allowed to dehisce individually. The number of seed in each ovary was then counted. Seed productivity was calculated on a site basis as follows:

Seed productivity (# seeds per m^2) = # female plants per site *
mean # catkins per female plant (data collected in 2006)*
mean # ovaries per catkin *
mean # of seeds per ovary) / area surveyed (m^2)

Germination Tests

Seeds were collected on all seed producing sites in 2006 and 2007 in order to examine annual and spatial variation in germination success. Catkins were allowed to dry overnight in a Petri dish at room temperature to allow for complete capsule dehiscence. The pappus was gently removed from all seeds and seeds were randomly selected for germination tests. In replicates of 5 or 10, seeds were placed onto moistened filter paper and tests were carried out in a growth chamber at 20°C for 14 hrs (light) and 10 hours (dark) with 85% humidity for 21 days. This protocol follows that of Bishop and Chapin (1989) however, the number of light hours was reduced to reflect the natural environment of the species. The number of seeds tested per site varied due to seed availability (N = 40 to 100). Germination was recorded daily throughout this period.

Seed Rain

During peak seed release (July 26 to August 8, 2006) seed rain was measured on sites with highest observed seed productivity (BK1AB, BKD and CNC). Seed rain traps consisted of a Petri dish, a waterproof Phero Tech© glue sheet (area = 25cm^2), and two thin metal holders which secured the trap to the ground. Twenty traps were set up and changed weekly on each site along 5 to 7 transects. Transects were located across the study site to achieve representative dispersion in all areas of the site. The distance from each trap to the nearest seed source was measured with a measuring tape. As *Salix* seeds are visually indistinguishable (Gage and Cooper 2005), and *S. jejuna* is the dominant *Salix* species on most sites (Chapter 2), it was assumed all *Salix* seeds found were of the study species.

Seed Addition

As it is known that *S.jejuna* seedlings grow well in alpine greenhouse soil mix under greenhouse conditions (Driscoll 2006), an experiment was designed to test the limitations of the natural *in situ* environment on seedling establishment. In late-July, 2006 seeds were planted on 7 sites in ground level containers of alpine greenhouse soil mix (N=25) (Memorial University of Newfoundland Botanical Garden) and in randomly located 0.5 m x 0.5 m plots (10 cm x 10 cm grid) of naturally occurring substrate (N=35). The alpine greenhouse soil mix was contained in an aluminium pan (22cm x 14 cm x 5 cm) secured to the ground with 4 thin metal wires. Containers were not buried to ground level to minimize disturbance to natural substrate. Ten seeds were planted in each experimental plot. Control plots (natural substrate) and control containers (alpine greenhouse soil mix) were also established, at the same time, for each treatment to control for natural seed rain. Controls were located 1 metre adjacent to experimental plots/containers. Following planting, plots were moistened to field capacity with distilled water. The number of seed addition plots established (Natural; N = 2-10, Alpine; N = 2-7) depended upon the amount of available seed as well as the size of the site (Table 2.1). In total, 350 and 250 seeds were planted in natural and alpine soil mix, respectively. Two alpine container plots were removed from the experiment on each of BK1-N and BKD-D due to wind damage. Seed emergence was monitored in early- and mid-August 2006, mid-October 2006, mid-June 2007 and late-July 2007. Because germination experiments were conducted at the same time as planting for this experiment, the maximum seedling emergence was a function of the germination rate determined through controlled germination tests.

Above and below ground clonal growth

To investigate the presence and extent of clonal growth, all adult plants (N = 51 - 385) were examined within study plots on all sites (N = 16-70). An individual plant or ramet was defined as a group of shoots emerging from a common stem/root complex. Above ground clonal growth was indicated by scarring on the main root collar complex; where a lateral branch had detached. On most plants placement of the "detachment" scar was correlated with the location of established lateral branches within 2-5 cm of the main root collar complex. This does not account for branches lost to wind or erosion and is used only as a comparative "index" of clonal growth. The number of adventitious roots per plant was also recorded as an indication of the potential for vegetative expansion. Clonal growth was then estimated using two methods; i) the number of detachment scars on the main root collar complex and ii) the presence of adventitious roots on at least one lateral branch.

To investigate under ground clonal growth excavations were carried out in September 2005 and May 2007 on three natural (BK1-N, BK39-N, CNC-N) and disturbed (BHD-D, CND-D, CNE-D) sites. In total, 35 plants were completely excavated, under appropriate Government harvest permits. Areas to be excavated were selected if there was above ground evidence of clonal growth and more than 4 plants. Plastic sheets were used to mark off a $1 m^2$ excavation area around each plant, providing a space for disturbed soil and protecting the surrounding area. Working within the designated area, substrate was gently removed around plant stems using hands and a soft brush. The area was examined for any possible interconnections between plants. All roots were followed to termination allowing for the examination of the root system. All excavated plants were later used as specimens for age determination in a companion study (Appendix III).

Data Analyses

All statistical analyses were performed in SAS® version 9.1 (SAS Institute Inc. 1996). Data were analyzed for normality, independence and homogeneity. If assumptions were not met for a general linear model then a generalized linear model was applied (Little et al. 2002). Where the response variable consisted of proportional data (i.e., proportion of seedlings, % seed germinated) the logistic regression using generalized linear model was used with binomial distribution (Lewis 2004). For all analyses, site was considered a fixed effect, nested within disturbance type, as all known occupied sites were used in this study.

Due to low seed emergence (<1%) and low seed rain (total <20 seeds) statistical analyses were not performed on results of the seed addition or seed rain experiments. However, a Spearman correlation was performed on pooled seed rain data to investigate the relationship between seed entrapment and distance to nearest seed source.

3.3 RESULTS

Demographic census

Natural seedling recruitment was very low on all sites (< 1 seedling /m^2) (Table 3.2), accounting for <5% of individuals within each surveyed population. Juveniles comprised a large proportion of plants at some sites (45.6%; BKD-D) but not others (Table 3.2). Across all sites, most adult plants were vegetative, ranging from 42.2% (BKD-D) to 89.7% (BK39-N), and reproductive (female) adults made up <10% of the population with the exception of CNA-N (20.8 %) (Table 3.2).

Disturbed sites, however, did have a significantly greater proportion of seedlings (natural= 0.7% ± 0.55%; disturbed= 2.7% ± 1.09%; df=1, χ^2=11.35, p=0.0008). Disturbance did not affect the proportion of juveniles (df=1, χ^2=1.35, p=0.246), reproductive (female) adults (df=1, χ^2=0.02, p=0.894), or vegetative adults (df=1, χ^2=1.26, p=0.262); however significant site variation was observed for each life stage, respectively (df=6, χ^2=50.40; χ^2=45.39; χ^2=33.00, p<0.001).

The density of all plants within the population (including all life stages) was not affected by disturbance type (natural= 6.01 ± 0.436 plants /m^2; disturbed=15.05 ± 2.08 plants /m^2; $F_{1,6}$=3.2977, p=0.1193) however there was significant site variation ($F_{1,6}$=137.27, p<0.0001), ranging from 3.4 plants /m^2 (CND-D) to 57.9 plants /m^2 (BKD-D).

Fruit and Seed Production

Disturbance type did not affect the number of female catkins produced per plant (natural=2.6 ± 0.5; disturbed= 3.3 ± 1.1; $F_{1,4}$=0.353, p=0.584), the number of ovaries per female catkin (natural=11.4 ± 1.7; disturbed=10.6 ± 0.9; $F_{1,4}$=0.195, p=0.681), nor the number of seeds per ovary (natural=6.4 ± 2.8; disturbed= 7.4 ± 1.4; $F_{1,4}$=0.088, p=0.7815) (Table 3.3). Significant site differences were found however in the mean number of female catkins per plant ($F_{4,149}$=3.38, p=0.011; Table 3.4) ranging from 1.7 (BHN-N) to 5.6 (CND-D) as well as the mean number of ovaries per catkin ($F_{4,136}$=6.02, p<0.001), ranging from 8.0 (CNA-N) to 13.6 (BK1-N). There was also significant site variation for the mean number of seeds per ovary ($F_{4,161}$=26.20, p<0.001).

Seed production varied widely both on a per site and per plant basis (Table 3.3) with BK1-N producing the highest density of seeds (472 seeds /m^2) and the most seed per plant (570 seeds). The lowest number of seeds produced per site was 34 seeds / m^2 (BHN-N) while per plant was 52 seeds (CNA-N). The catkin production at two sites was too low to calculate seed production (BK39-N and CNC-N). Differences in fruit and seed production among sites cannot be accounted for by sex ratio as the proportion of males and females were similar between disturbance type (df=1, χ^2=0.05, p=0.8269) and among sites (df=6, χ^2=4.71, p=0.5813).

Germination Tests

A significant interaction between disturbance type and year (df=1, X^2=13.36, p=0.0003) was found, therefore, the analysis was split further to examine the effect of disturbance within each year and variation displayed among sites. Seed germination differed between disturbance types in 2007 (df=1, X^2=9.32, p=0.0023) with a mean germination success of 65.3% ± 6.6% on natural sites and 76.3% ± 12.7% on disturbed sites. Germination success varied among sites in 2007 (df=5, X^2=58.78, p<0.001) ranging from 51% ± 3.5% (CND-D) to 89% ± 2.8 % (BKD-D), with two disturbed sites having the highest germination success (BKD-D and CNE-D). Germination success was much lower in 2006 and did not differ between disturbance types (natural = 23.7% ± 9.2%; disturbed = 13.7% ± 7.5%; df=1, X^2=0.00, p=1.000), however, there was significant site variation (df=5, X^2=33.77, p<0.001).

Efforts were made to collect the seeds at the same phenological stage in both years (i.e., fruit was dry and had begun to dehisce naturally). Female plants were flowering on June 8th in 2006 and June 4th in 2007. Seeds were harvested on July 26th in 2006 and July 24th in 2007. Even though seeds were collected at what appeared to be the same phenological stage, differences in germination success between years may have been influenced by differences in male flowering times as males had released all pollen at an earlier date in 2006 than in 2007.

Table 3.2 Summary of single-census data (2006) for *S. jejuna*, on naturally-(N) and anthropogenically-disturbed (D) substrates on the limestone barrens of Newfoundland (Canada). Only an accurate estimate of the number of female plants surveyed per plot could be made as male plants were finished flowering at the time of sampling. Therefore, male plants are included in vegetative plants for all sites.

	NATURAL						DISTURBED			
	BHN-N	BK1-N	BK39-N	CNA-N	CNC-N	Mean	BKD-D	CND-D	CNE-D	Mean
Area surveyed (m^2)	31	35	30	66	35	**39.4 ± 6.72**	16	70	22	**36.0 ± 17.09**
Total No. plants surveyed	137	302	185	240	105	**193.8 ± 35.38**	204	234	443	**293.7 ± 75.17**
% Seedlings[a]	0.00	0.66	0.00	0.00	2.86	**0.7 ± 0.55**	4.90	1.71	1.58	**2.7 ± 1.09**
% Juveniles[a]	3.65	10.93	8.11	3.33	22.86	**9.8 ± 3.57**	45.59	2.99	4.97	**17.8 ± 13.88**
% Reproductive adults (♀)[a]	7.30	9.6	2.16	20.83	8.57	**9.7 ± 3.06**	7.35	7.69	7.67	**7.6 ± 0.11**
% Vegetative adults[a]	89.05	78.81	89.73	75.83	65.71	**79.8 ± 4.47**	42.16	87.61	85.78	**71.9 ± 14.85**
No. of seedlings (/m^2)	0	0.06	0	0	0.09	**0.0 ± 0.02**	0.63	0.06	0.32	**0.3 ± 0.16**
No. of juveniles (/m^2)	0.16	0.94	0.5	0.12	0.69	**0.5 ± 0.16**	5.81	0.10	1.00	**2.3 ± 1.77**
No. of reproductive adults (♀) (/m^2)	0.32	0.83	0.13	0.76	0.26	**0.5 ± 0.14**	0.94	0.26	1.55	**0.9 ± 0.37**
No. of vegetative adults (/m^2)	3.94	6.80	5.53	2.76	1.97	**4.2 ± 0.88**	5.38	2.93	17.27	**8.5 ± 4.43**

[a] indicates proportion of life stage in total population surveyed

Table 3.3 Fruit and seed production at various morphological levels (mean ± SE) for naturally- (N) and anthropogenically-disturbed (D) *S. jejuna* study sites, collected on the limestone barrens of Newfoundland (Canada); (♀= female plant).

Site	# ♀ per site	Mean # catkins per female (N=9-59)	Mean # ovaries per catkin (N=20)	Mean # seeds per ovary (N=18-33)	Seed produced per (m^2)	Seed produced per plant
NATURAL						
BHN-N	10	1.7 ± 0.3	12.7 ± 1.5	4.9 ± 0.8	33.8	104.9
BK1-N	29	3.5 ± 0.6	13.6 ± 1.0	11.9 ± 0.7	472.1	569.8
CNA-N	50	2.7 ± 0.4	8.0 ± 0.8	2.4 ± 0.6	39.3	51.9
Mean		**2.6 ± 0.5**	**11.4 ± 1.7**	**6.4 ± 2.8**	**181.7 ± 145.2**	**242.2 ± 164.5**
DISTURBED						
BKD-D	15	1.9 ± 0.3	9.6 ± 0.6	9.6 ± 0.6	163.8	174.7
CND-D	18	5.6 ± 1.6	12.3 ± 0.8	4.9 ± 0.7	87.5	340.4
CNE-D	34	2.5 ± 0.5	9.8 ± 0.7	7.6 ± 0.8	286.2	185.2
Mean		**3.3 ± 1.1**	**10.6 ± 0.9**	**7.4 ± 1.4**	**179.2 ± 57.9**	**233.4 ± 53.6**

Table 3.4 Comparison of mean germination success ± SD of *S. jejuna* seed collected on both naturally- (N) and anthropogenically-disturbed (D) populations, at the beginning of seed release in 2006 and 2007, on the limestone barrens of Newfoundland (Canada).Due to low seed production seed was not collected at BK39-N both years and CNC-N in 2007.

Site	2006 (%)	2007 (%)
NATURAL		
BHN-N	0 ± 0	77 ± 2.71
BK1-N	32 ± 5.5	54 ± 4.6
CNA-N	20 ± 0	65 ± 9.6
CNC-N	43 ± 4.0	*
Mean	**23.7 ± 9.2**	**65.3 ± 6.6**
DISTURBED		
BKD-D	26 ± 3.1	89 ± 3.5
CND-D	15 ± 5.0	51 ± 3.5
CNE-D	0 ± 0	89 ± 2.8
Mean	**13.7 ± 7.5**	**76.3 ± 12.7**

Seed rain

Overall seed rain was low on all sites examined with only 20 seeds captured in total (total area on all sites (N=3) = 1500 cm^2). On August 3rd, 2007, BK1-N, CNC-N and BKD-D had 5, 3 and 4 seeds in the traps, respectively. The number of seed falling on site the following week was lower with 2, 1 and 1 seeds trapped, respectively. Based on seed productivity by site (Table 3.3), the probability of capturing a seed in a seed trap would be highest on BK1-N, CND-D then CNE-D.

Using pooled data there was no significant relationship between the number of seeds found in the seed trap and the distance of the trap to the nearest seed source ($r = -0.013$, $p= 0.920$). The mean distance to the nearest seed producing plant was 1.14m; however, a greater sample size is needed to fully understand seed rain and seed dispersal.

Seed addition experiment

On site seed germination was very low with only 1 seed emerging of the 600 seeds planted in total. This seed emerged on naturally-disturbed substrate at CNC-N, which had the highest seed germination success in 2006 at 43% ± 4%. There was no natural recruitment into any of the alpine green house soil addition containers or control plots in 2006 or 2007, indicating establishment may be limited by field environmental conditions (e.g., soil moisture, temperature) and not likely substrate condition.

Clonal Growth

Excavations (N=35) indicate plants are not connected underground and that *S. jejuna* has a shallow root system, 5 to 25 cm deep with many narrow, fibrous roots in the upper soil layer. The percentage of plants with detachment scarring ($df=1$, $\chi^2=19.00$, $p<0.001$) and adventitious roots ($df=1$, $\chi^2=4.85$, $p=0.0277$) was affected by disturbance type (Figure 3.1). The mean percentage of plants with detachment scarring on natural sites was 39.6% ± 15.1% versus 22.4% ± 8.9% on disturbed sites. Natural sites had a mean percentage of plants with adventitious roots of 20.9% ± 6.6% versus 9.7% ± 3.5% on disturbed sites. Plants on natural sites were nearly 8 times more likely to have detachment scarring and 3 times more likely to have adventitious roots than plants growing on disturbed substrate. Site differences were also observed for both components of the clonal "index", respectively (df=6, χ^2=418.78, χ^2= 178.25, p<0.001).

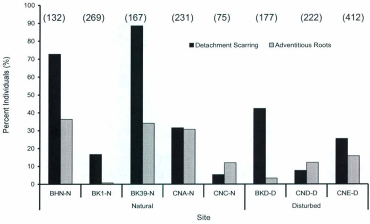

Figure 3.1 Differences in components of clonal growth in populations of *S. jejuna* on natural and anthropogenically-disturbed habitat of the limestone barrens of Newfoundland (Canada); detachment scarring on main root collar complex and adventitious root growth present on at least one lateral branch; Sample size per site is indicated above the bar; only includes adult plants.

The percentage of plants with detachment scarring ranged from 5.3% (CNC-N) to 89% (BK39-N). Sites with the highest degree of detachment scarring also had the highest percentage of plants with adventitious roots (34%, BK39-N; 36%, BHN-N), providing opportunity for new branches to establish and potentially become independent from the parent plant.

Variation within species range

Overall, there was no geographical relationship among reproductive and demographic parameters. Even sites located nearest to each other displayed different reproductive patterns; one would expect CNA-N and CNC-N to be relatively similar as these sites are located approximately 1 km apart and have similar substrate and vegetation patterns (Chapter 2). However, CNA-N had a considerably lower proportion of juveniles and higher proportion of reproductive adults than CNC-N (Table 3.2).

Site variation within anthropogenically-disturbed sites could potentially be accounted for by disturbance intensity however there is no apparent pattern for reproductive or demographic parameters. CND-D, the most severely disturbed site (intensity level 3) did experience low germination rates in both 2006 and 2007 however germination success was comparable to other natural sites (e.g., BHN-N).

3.4 DISCUSSION

Populations of *S. jejuna* that inhabit anthropogenically-disturbed substrates have a greater proportion of seedlings and are less likely to display clonal growth than populations on naturally-disturbed substrates. Moreover, this study indicates even low levels of disturbance have the potential to disrupt the natural reproductive patterns of this endangered, endemic species, which may have long term consequences for persistence. Therefore, it is recommended that *in situ* conservation plans firstly focus on ensuring high adult survival within natural habitats, including the elimination of all trampling sources (e.g., off road vehicles). This work also suggests that demographic monitoring should be given high priority in the recovery planning for *S. jejuna* and other rare woody clonal species. Long term data may indicate that anthropogenically-disturbed habitats require active restoration to improve ecosystem processes which affect reproduction.

Effect of disturbance on reproduction

This study found that *S. jejuna* does not reproduce clonally via underground rhizomes; instead, clonal growth occurs above ground when lateral branches, extending from the main root collar complex, establish through adventitious roots, on the underside of the branch. The main root collar complex decays through natural processes (e.g., wind, substrate erosion, ice scouring) and lateral branches break away becoming independent plants. This process was evident by the presence of numerous decayed root collar complexes situated in the middle of 2-3 lateral branches. Many times the root collar complex and the lateral branches were still in contact even though they were detached. This "layering" growth pattern has been observed in other *Salix* species on the limestone barrens; *S. urva-ursi* and *S. reticulata* (M. Burzynski, pers comm.) However, it appears as though Beschel and Webb (1963) are the only other study to have described this growth pattern, in prostrate *Salix*, under similar climatic conditions.

Figure 3.2 Individual *S. jejuna* plant displaying above ground clonal growth patterns of main root collar complex deterioration (circle) and lateral branch layering at the naturally-disturbed site of Cape Norman (CNA-N), on the northern limestone barrens of Newfoundland (Canada).

They noted that in *S. arctica* the main "burl" becomes decayed and accessory roots develop near the base of lateral branches. Their research indicated that individual prostrate branches live for a much shorter time than the central burl. Sampson and Jones (1977) described *S. glauca* in Arctic Norway as dropping branches but made no reference to the main bole decaying or the presence of adventitious roots. As noted by Beschel and Webb (1963), this type of growth pattern affects individual longevity. In a companion study, it was determined the median age of adult plants within six *S. jejuna* populations ranged from 9 years to 15.5 years (main root collar complex) with a maximum age of 40 years (Appendix III). This was unexpected as many arctic-alpine *Salix* species are typically older in age; e.g., *S. arctica* minimum age values ranged from 18 to 87 years in the Canadian Arctic (Beschel and Webb 1963) and between 16 to 94 years, with a median age of 31 years, in Northeast Greenland (Schmidt et al. 2006). *S. alaxensis*, another prostrate clonal shrub ranged up to 74 years in the North West Territories (Zalatan and Gajewski 2006). This work suggests that the young age of the studied *S. jejuna* populations could be a function of this unique clonal growth strategy where the main root collar complex of the parent plant degrades, leaving only younger established lateral branches. This will have consequences on the genetic structure and variation of populations.

These findings also indicate that the degree of clonal growth is dependent upon disturbance type and may have overall affects on population dynamics. Plants growing on naturally-disturbed substrates were 8 times more likely to have detachment scarring and 3 times more likely to have adventitious roots when compared to anthropogenically-disturbed populations. Although this study represents just one "snapshot" in the demographic history of this species, it is evident that the population dynamics of natural, clonal populations may be different than those of disturbed, non clonal populations. Two sites with the highest level of clonal growth (BHN-N and BK39-N) had the greatest proportion of vegetative plants (~89%), few reproductive adults (2-7%) and no seedlings detected; these sites also had little seed production. On these sites, clonal growth appears to provide for population maintenance when conditions are less favourable for seed production and seedling establishment (Bierzychudek 1985). This observation also follows the theory which suggests that in stressful environments plants will exhibit a life history that emphasizes stasis of adult stages at the expense of growth and fecundity (Grime 1977; see Garcia & Zamora 2003).

Disturbance has been shown to influence the success of different reproductive strategies in alpine environments by altering the physical and environmental soil conditions (Chambers 1995; Forbes 1992). The findings of this study suggest that clonal growth is reduced on anthropogenically-disturbed substrates because of the reduction in fine grained sediment and soil moisture (Driscoll 2006; Chapter 2), which is required to promote rooting. Though research addressing the factors that affect the production of adventitious roots in *Salix* species is limited (e.g., *S. setchelliana,* Douglas 1987; *S. planifolia,* Houle and Babeux 1998), it is also speculated that the larger sized particles on anthropogenically-disturbed sites increase surface relief, potentially reducing erosion to plants by wind and substrate which then decreases the pronounced deterioration of the parent plant (main root collar complex), as observed on naturally-disturbed substrates.

In addition, although limited throughout species range, habitat changes on anthropogenically-disturbed substrates resulted in increased seedling densities, when compared to naturally-disturbed substrates. The predominance of larger particle sizes and increased surface relief of anthropogenic habitat may provide refuge for seeds in this very windy environment and facilitate higher germination rates by promoting seed entrapment (Harper 1977; Stamp 1984). Increased seedling emergence has been observed in other alpine environments on anthropogenically-disturbed habitat (Freedman et al. 1982; 1780 / m^2 on disturbed soils versus 180 / m^2 on undisturbed soils), though the mechanisms which promote establishment on disturbed soils are not fully understood.

As is common in other arctic-tundra *Salix* (e.g., *S. glauca* - Sampson & Jones 1997), it was expected that seedling recruitment would be low throughout species range. Even within highly sexually productive populations (e.g., BK1-N), sites had low seed rain suggesting that a high proportion of seed is dispersed outside of site boundaries, into fully vegetated areas that are not suitable for seed germination and seedling establishment, as suggested by Driscoll (2006).

In addition to being limited by propagule availability, this research suggests seedling recruitment appears to be further limited by the environmental (e.g., soil temperature) and physical conditions (e.g., nutrients) of natural habitat. This is evident by the low emergence rates in field seed additions (<1%), even on sites with high viability in 2006 (e.g., CNC-N 43%, BK1-N 32%). This finding is consistent with results of a similar study by Driscoll (2006) who in 2004 observed low emergence rates (~3%) when seeds were planted on natural substrate, even when *ex situ* germination tests yielded 81% emergence. No emergence on the alpine greenhouse soil mix further supports limitations to seed emergence by natural environmental conditions as controlled greenhouse studies showed high emergence rates of *S. jejuna* on this soil mix (Robinson, unpublished data; Driscoll 2006). Low recruitment however, should not be a conservation concern for *S. jejuna* as research has shown that even rare establishment by seed is adequate to maintain genetic diversity (Watkinson & Powell 1993).

Spatial and temporal variation observed in sexual reproduction parameters (e.g., seed productivity, germination rate), throughout species range, may reflect differences in habitat structure within naturally-disturbed sites and habitat quality within anthropogenically-disturbed sites (Chapter 2). In the rare *Gentiana pneumonanthe*, Oostermeijer et al. (1998) found that habitat characteristics such as the amount of ammonium, potassium, calcium, and sulphate positively affected the number of ovules among populations. Therefore, nutrient content could be a possible explanation for site variation in *S. jejuna* seed productivity or, as observed in *S. setchelliana*, variation may be explained by differences in pollinator suitability and availability (Douglas 1997).

Conservation implications of anthropogenic disturbance

The discovery that anthropogenic disturbance has the potential to alter the natural demography of *S. jejuna* poses a series of questions to recovery planners; will existing natural populations be sufficient to allow for long term species persistence? And, can anthropogenically-disturbed habitat support self-sustaining populations without active restoration?

Firstly, though a portion of *S. jejuna*'s habitat is anthropogenically-disturbed, it is important to note the implications of this research on overall habitat protection, independent of disturbance type. As there are proportionately higher levels of adults within all populations, and clonal growth appears to be the primary method of population sustainability, there is an immediate need to implement habitat protection measures that ensure adult survival and reduce further degradation to natural habitats. Ensuring adult survival can also act as a buffer against temporal and spatial variation (e.g., recruitment, germination success, seed production, and environmental conditions). The removal of trampling sources, such as off-road vehicles or mountain bikes, within all habitat types, will aid efforts to ensuring high adult survival by eliminating physical damage to plants and long term damage to habitat (Rafuse 2005).

Anthropogenic disturbance has been shown to mediate changes to life history in other narrow endemic species, as observed in *S. jejuna*. Disturbed road populations of the endangered herb *Hypericum cumulicola* displayed increased fecundity when compared to natural fire-maintained scrub populations (Quintana-Ascencio et al. 2007). Though Quintana-Ascenio et al. (2007) suggest that road populations may promote species persistence when scrub populations are reduced between natural disturbance events (e.g., fire), their research demonstrates that road populations are less stable. Moreover, anthropogenically-disturbed populations of rare *Braya* species, on the limestone barrens, were also found to be less persistent (Noel 2000), with larger individuals and greater seed production (Squires 2010). These studies suggest that increased seedling emergence within anthropogenically-disturbed populations of *S. jejuna* may be indicative of reduced species persistence.

While it is important to acknowledge the possible benefits of increased recruitment (e.g., adaptation to changing environment, greater genetic diversity) to species long-term survival, it could be assumed that the tendency towards clonal reproduction within populations on natural substrate have allowed this species to persist in this harsh environment and are congruent with the continuing conservation of this species.

Therefore, in summary, it is recommended that conservation efforts for this species focus on the implementation and enforcement of habitat protection measures such as the removal of off-road vehicles within all habitat types. Following a precautionary approach, it is suggested that anthropogenically-disturbed habitat be restored to reflect adjacent undisturbed natural habitat and long term demographic monitoring be continued to evaluate whether restorative efforts have promoted the reproductive traits of natural populations.

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3.5 REFERENCES

Alliende MC, Harper JL (1989) Demographic studies of a dioecious tree. I. Colonization, sex, and age structure of a population of *Salix cinerea*. Journal of Ecology 77:1029-1047

Alstrom-Rapaport C, Lascoux M, Gullberg U (1997) Sex determination and sex ratio in the dioecious shrub *Salix viminalis* L. Theoretical and Applied Genetics 94: 493-497

Anions MFE (2000) COSEWIC status report on Barrens Willow, *Salix jejuna*. Committee on the Status of Endangered Wildlife in Canada. 24 pp.

Argus GW (1965) The taxonomy of the *Salix glauca* complex in North America. Contributions from the Gray Herbarium University 196:1-142

Auerbach NA, Walker MD, Walker DA (1997) Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. Ecological Applications 7: 218-235

Banfield C (1983) Climate. In: South RG (ed) Biogeography and Ecology of the Island of Newfoundland, Junk Publishers, Boston, USA

Barsoum N (2002) Relative contributions of sexual and asexual regeneration strategies in *Populus nigra* and *Salix alba* during the first years of establishment on a braided gravel bed river. Evolutionary Ecology 15:255-279

Beerling DJ (1998) Biological flora of the British Isles: *Salix herbacea* L. Journal of Ecology 86: 872-895

Beschel RE, Webb D (1963) Growth ring studies on Arctic willows, Preliminary Report 1961-1962, Axel Heiberg Island Research Reports, pp 189-198.

Bierzychudek P (1985) Patterns in plant parthenogenesis. Experientia 41:1255-1264

Bishop SC, Chapin FS III (1989) Establishment of *Salix alaxensis* on a gravel pad in arctic Alaska. Journal of Applied Ecology 26:575-583

Bouchard A, Hay S, Brouillet L, Jean M, Saucier I (1991) The rare vascular plants of the Island of Newfoundland. Syllogeus No. 65.

Bret-Harte MS, Shaver GR, Chapin FS III (2002) Primary and secondary stem growth in arctic shrubs: implications for community response to environmental change. Journal of Ecology 90:251-267

Burzynski M. E-mail correspondence with J. Robinson. April (2009) Ecologist, Parks Canada Western NL Field Unit, Parks Canada Agency, Port au Choix, Newfoundland, Canada.

Chambers JC (1995) Disturbance, life history strategies, and seed fates in alpine herbfield communities. American Journal of Botany 82:421-433

Crawford RMM, Balfour J (1983) Female predominant sex ratios and physiological differentiation in arctic willows. Journal of Ecology 71:149-160

Densmore R, Zasada J (1983) Seed dispersal and dormancy patterns in northern willows: ecological and evolutionary significance. Canadian Journal of Botany 61: 3207-3216

Djan-Chékar N, Hermanutz L, Ballam D, Bell T, Brazil J, Mann H, Maunder J, Meades SJ, Nicholls W, Soper L, Yetman G (2003) Recovery strategy for Barrens Willow (*Salix jejuna* Fernald). Inland Fish and Wildlife Division, Government of Newfoundland and Labrador, Corner Brook 11 pp.

Donato E (2005) Climatology of the Limestone Barrens, Northern Peninsula, Newfoundland: Implications for rare plant phenology and distribution. M.Sc. Thesis. Department of Geography, Memorial University, St. John's, Newfoundland, Canada

Douglas DA (1987) Growth of *Salix setchelliana* on a Kluane river point bar, Yukon Territory, Canada. Arctic and Alpine Research 19:35-44

Douglas DA (1989) Clonal growth of *Salix setchelliana* on glacial river gravel bars in Alaska. Journal of Ecology 77:112-126

Douglas DA (1994) Seed germination, seedling demography, and growth of *Salix setchelliana* on glacial river gravel bars in Alaska. Canadian Journal of Botany 73:673-679

Douglas DA (1997) Pollination, capsule damage, and the production of seeds in *Salix setchelliana* (Salicaceae), an Alaskan glacial river gravel bar willow. Canadian Journal of Botany 75:1182-1187

Douglas DA, Jones MH, Pokhilko A (1997) Growth habits of *Salix polaris* in snowbeds in the Khibini Mountains, Kola Peninsula, Russia. Botanica Helvetica 107:83-90

Douhovnikoff V, McBride JR, Dodd RS (2005) *Salix exigua* clonal growth and population dynamics in relation to disturbance regime variation. Ecology 86: 446-452

Driscoll J (2006) *Ex situ* conservation protocols for the rare plants *Braya longii* (endangered), *Braya fernaldii* (threatened) (Brassicaceae) and *Salix jejuna* (endangered) (Salicaceae), endemic to the Limestone Barrens of Newfoundland. M.Sc. Thesis. Department of Biology, Memorial University, St. John's, Newfoundland, Canada

Fernald ML (1950) Gray's Manual of Botany. Dioscorides Press, Portland Oregon, USA

Fiedler PL, Ahouse JJ (1992) Hierarchies of cause: toward an understanding of rarity in vascular plant species. In: Fiedler PL and Jain SK (eds) Conservation biology: The theory and practice of nature conservation, preservation and management, Chapman & Hall, New York, USA

Forbes BC (1992) Tundra disturbance studies. II. Plant growth forms of human -disturbed ground in the Canadian Far North. Muskox 39:46-55

Freedman B, Hill N, Svoboda J, Henry G (1982) Seed banks and seedling occurrence in a high Arctic oasis at Alexandra Fjord, Ellesmere Island, Canada. Canadian Journal of Botany 60:2112-2118

Gage EA, Cooper DJ (2005) Patterns of willow seed dispersal, seed entrapment, and seedling establishment in a heavily browsed montane riparian ecosystem. Canadian Journal of Botany 83: 678-687

Garcia D, Zamora R (2003) Persistence, multiple demographic strategies and conservation in long-lived Mediterranean plants. Journal of Vegetation Science 14: 921-926

Greene S (2002) Substrate characteristics of *Braya* habitat on the limestone barrens, Great Northern Peninsula, Newfoundland. B.Sc. Thesis. Memorial University, St. John's, Newfoundland, Canada

Grime JP (1977) Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. American Naturalist 11:1169-1194

Grime JP (1979) Plant strategies and vegetation processes. John Wiley & Sons, New York

Hakkarainen H, Roininen H, Virtanen R (2005) Negative impact of leaf gallers on arctic-alpine dwarf willow, *Salix herbacea*. Polar Biology 28:647-651

Harper JL (1977) Population Biology of Plants. Academic Press, Toronto, Canada

Hermanutz LA, Mann H, Anions MFE, Ballam D, Bell T, Brazil J, Djan-Chékar N, Gibbons G, Maunder J, Meades SJ, Nicholls W, Smith N, Yetman G. 2002). National Recovery Plan for *Braya longii* and *B. fernaldii*. National Recovery Plan No. 23. Recovery of Nationally Endangered Wildlife (RENEW), Ottawa, Ontario, Canada.

Hoekstra JM, Boucher TM, Ricketts TH, Roberts C (2005) Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8:23-29

Houle G, Babeux P (1998) The effect of collection date, IBA, plant gender, nutrient availability, and rooting volume on adventitious root and lateral shoot formation by *Salix planifolia* stem cuttings from the Ungava Bay area (Quebec, Canada). Canadian Journal of Botany 76:1687-1692

Jones MH, Macdonald SE, Henry GHR (1999) Sex- and habitat-specific responses of a high arctic willow, *Salix arctica*, to experimental climate change. Oikos 87:129-138

Kikuchi S, Suzuki W, Kanazashi NBA, Yoshimaru H (2005) Characterization of eight polymorphic microsatellites in endangered willow *Salix hukaonana*. Molecular Ecology Notes 5:869–870

Krukeberg AR, Rabinowitz D (1985) Biological aspects of endemism in higher plants. Annual Review of Ecology and Systematics 16:447-479

Lamont BB, He T, Enright NJ, Krauss SL, Miller BP (2003) Anthropogenic disturbance promotes hybridization between *Banksia* species by altering their biology. Journal of Evolutionary Biology 16:551-557

Lascoux M, Thorsén J, Gullberg U (1996) Population structure of a riparian willow species, *Salix viminalis* L. Genetic Research 68:45-54

Lewis K (2004) How important is the statistical approach for analyzing categorical data? A critique using artificial nests. Oikos 104:305-315

Little RC, Stroup WW, Freund RJ (2002) SAS for Linear Models, Fourth Edition, SAS Institute Inc, Cary, NC, USA

Maschinski J, Baggs JE, Sacchi CF (2004) Seedling recruitment and survival of an endangered limestone endemic in its natural habitat and experimental reintroduction sites. American Journal of Botany 91:689-698

Maschinski J, Frye R, Rutman S (1997) Demography and population viability of an endangered plant species before and after protection from trampling. Conservation Biology 11:990-999

Martorell C (2007) Detecting and managing an overgrazing-drought synergism in the threatened *Echeveria longissima* (Crassulaceae): the role of retrospective demographic analysis. Population Ecology 49:115-125

Martorell C, Peters EM (2005) The measurement of chronic disturbance and its effects on the threatened cactus *Mammillaria pectinifera*. Biological Conservation 124:199-207

McIntyre S, Lavorel S (1994) Predicting richness of native, rare, and exotic plants in response to habitat and disturbance variables across a variegated landscape. Conservation Biology 8:521-531

McIntyre S, Lavorel S, Tremont RM (1995) Plant life-history attributes: Their relationship to disturbance response in herbaceous vegetation. Journal of Ecology 83:31-44

McLeod KW, McPherson JK (1973) Factors limiting the distribution of *Salix nigra*. Bulletin of the Torrey Botanical Club 100:102-110

Morris AB, Small RL, Cruzan MB (2004) Variation in frequency of clonal reproduction among populations of *Fagus grandifolia* Ehrh. in response to disturbance. Castanea 69:38-51.

Niiyama K (1990) The role of seed dispersal and seedling traits in colonization and coexistence of *Salix* species in a seasonally flooded habitat. Ecological Research 5:317-331

Noel L (2000) The effect of disturbance on the seedling recruitment and persistence of *Braya longii* and *Braya fernaldii*. Honours Thesis. Department of Biology, Memorial University, St. John's, Newfoundland, Canada

Oostermeijer JGB, Luijten SH, Krenova ZV, Den Nijs HCM (1998) Relationships between population and habitat characteristics and reproduction of the rare *Gentiana pnemonanthe* L. Conservation Biology 12:1042-1053

Pakeman RJ, Torvell L (2008) Identifying suitable restoration site for a scare subarctic willow (*Salix arbuscula*) using different information sources and methods. Plant Ecology & Diversity 1:105-114

Parsons K, Hermanutz L (2006) Conservation of rare, endemic braya species (Brassicaceae): Breeding system variation, potential hybridization, and human disturbance. Biological Conservation 128:201-214

Pavlovic NB (1994) Disturbance-dependent persistence of rare plants: anthropogenic impacts and restoration implications. In: Bowles ML and Whelan CJ (ed) Restoration of endangered species: Conceptual issues, Planning and Implementation, Cambridge University Press, New York, USA

Predavec M, Danell K (2001) The role of lemming herbivory in the sex ratio and shoot demography of willow populations. Oikos 92: 459-466

Purdy BG, Bayer RJ (1995) Allozyme variation in the Athabasca sand dune endemic, *Salix silicicola*, and the closely related widespread species, *S. alaxensis*. Systematic Botany 20:179-190

Purdy BG, Bayer RJ, Macdonald SE (1994) Genetic variation, breeding system evolution, and conservation of the narrow sand dune endemic *Stellaria arenicola* and the widespread *S. longipes* (Caryophyllaceae). American Journal of Botany 81:904-911

Quintana-Ascencio PF, Weekley CW, Menges ES (2007) Comparative demography of a rare species in Florida scrub and road habitats. Biological Conservation 137:263- 270.

Rafuse G (2005) The impact of off-road vehicles on the Limestone Barrens habitat and resident plants endemic to the Great Northern Peninsula, Newfoundland, Canada. Honours Thesis. Memorial University, St. John's, Newfoundland, Canada.

Reisch C, Schurm S, Poschlod P (2007) Spatial genetic structure and clonal diversity in an alpine population of *Salix herbacea* (Salicaceae). Annals of Botany 99:647- 651.

Rossi G, Parolo G, Zonta LA, Crawford JA, Leonardi A (2006) *Salix herbacea* L. fragmented small population in the N-Apennines (Italy): Response to human trampling disturbance. Biodiversity and Conservation 15:3881-3893

Royal Botanical Gardens, Kew (2006) A field manual for seed collectors. <http://www.kew.org/msbp/scitech/publications/fieldmanual.pdf> Accessed 1 May 2006

Sacchi CF, Price PW (1992) The relative roles of abiotic and biotic factors in seedling demography of Arroyo Willow (*Salix lasiolepis*: Salicaceae). American Journal of Botany 79: 395-405

Sampson EJ, Jones BM (1977) The productivity of *Salix glauca* L. in Arctic Norway. Annals of Botany 41:155-161

SAS Institute Inc. (1996) SAS/STAT user's guide, release 6.12 ed. SAS Institute Inc., Cary, North Carolina, USA

Schmidt NM, Baittinger C, Forchhammer MC (2006) Reconstructing century-long snow regimes using estimates of high arctic *Salix arctica* radial growth. Arctic, Antarctic, and Alpine Research 38:257-262

Shafroth PB, Scott ML, Friedman JM, Laven RD (1994) Establishment, sex structure and breeding system of an exotic riparian willow, *Salix x rubens*. The American Midland Naturalist 132:159-172

Species at Risk Act. (2003). Species at Risk Act, Statutes of Canada. Canada Gazette. Queen's Printer for Canada, Ottawa, Ontario.

Squires S (2010) Insect pests and pathogens compromise the persistence of two endemic and rare *Braya* (Brassicaceae). PhD Thesis. Department of Biology, Memorial University, St. John's, Newfoundland, Canada.

Stamati K, Hollingsworth PM, Russell J (2007) Patterns of clonal diversity in three species of sub-arctic willow *Salix lanata*, *Salix lapponum* and *Salix herbacea*. Plant Systematics and Evolution 269:75-88

Stamp NE (1984) Self-burial behavior of *Erodium cicutarium* seeds. Journal of Ecology 72:611-620

Sutton JT, Hermanutz L, Jacobs JD (2006) Are frost boils important for the recruitment of Arctic-Alpine plants? Arctic, Antarctic & Alpine Research 38:273-275

Terzioğlu S, Cokunçelebi K, Serdar B (2007) Contribution to the description of an endemic Turkish *Salix* species. Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology 141:82-85

Tolvanen A, Schroderus J, Henry GHR (2002) Age- and stage-based bud demography of *Salix arctica* under contrasting muskox grazing pressure in the high arctic. Evolutionary Ecology 15: 443-462

Ueno N, Suyama Y, Seiwa K (2007) What makes the sex ratio female-biased in the dioecious tree *Salix sachalinensis*? Journal of Ecology 95:951-959

Ureta C, Martorell C (2009) Identifying the impacts of chronic anthropogenic disturbance on two threatened cacti to provide guidelines for population-dynamics restoration. Biological Conservation 142:1992-2001

Walck JL, Baskin JM, Baskin CC (1999) Roles of succession, light, nutrients and disturbance on population vigor and maintenance of the rare plant *Solidago shortii* (Asteraceae). Plant Ecology 145:133-147

Watkinson AR, Powell JC (1993) Seedling recruitment and the maintenance of clonal diversity in plant populations – a computer simulation of *Ranunculus repens*. Journal of Ecology 81: 707-717

Wijk S (1986a) Influence of climate and age on annual shoot increment in *Salix herbacea*. Journal of Ecology 74:685-692

Wijk S (1986b) Performance of *Salix herbacea* in an alpine snow-bed gradient. Journal of Ecology 74:675-684

Woods SW, Cooper DJ (2005) Hydrological factors affecting initial willow seedling establishment along a subalpine stream, Colorado, U.S.A. Arctic, Antarctic, and Alpine Research 37:636-643

Yan Q, Liu Z, Ma J, Jiang D (2007) The role of reproductive phenology, seedling emergence and establishment of perennial *Salix gordejevii* in active sand dune fields. Annals of Botany 99:19-28

Zalatan R, Gajewski K (2006) Dendrochronological potential of *Salix alaxensis* from the Kuujjua river area, western Canadian Arctic. Tree-Ring Research 62:75

4.0 THESIS SUMMARY AND CONCLUSION

This thesis describes the investigation of the effects of anthropogenic disturbance on the habitat and reproductive traits of the endangered, endemic *Salix jejuna*. The goal of this research was to provide scientifically defensible information that would promote the development of effective *in situ* conservation strategies to encourage the preservation of *S. jejuna* within its unique limestone barrens habitat.

The assessment of habitat features revealed marked differences in the substrate and vegetation between naturally- and anthropogenically-disturbed habitats. Anthropogenic habitat had greater gravel content, less exposed bedrock, decreased soil moisture, increased total nitrogen and decreased phosphorus content when compared to naturally-disturbed substrates. Anthropogenic habitat also lacked clear patterned ground formed through frost activity as observed within natural habitat. Textural analysis revealed that anthropogenically-disturbed substrates are also reduced in fine and medium sand content, which is thought to play an integral role in the ability for *S. jejuna* to reproduce clonally.

Though total vegetation cover did not differ between disturbance types, anthropogenically-disturbed habitat was found to have increased bare ground and herbaceous cover, with reduced bryophyte cover. Unlike the revegetation of degraded alvars, but as is common in the revegetation of disturbed arctic-tundra areas, there was no major shift in the vascular plant species assemblage nor were any non-native invasive species observed on anthropogenically-disturbed habitat.

S. jejuna was found to have a greater coverage within anthropogenically-disturbed habitat, having greatest coverage when woody plant cover was less than 50%, when bryophyte cover was less than 20%, and when bare ground cover exceeded 60%. *S. jejuna* also showed positive associations with *Plantago maritima*, *Salix reticulata, Saxifrage oppositifolia* and strong negative associations with other dominant woody species such as *Dryas integrifolia*, *Juniperus horizontalis* and *Empetrum nigrum*.

It is suggested that the reduction of fine grained particles on anthropogenically-disturbed substrates leads to reduced moisture retention and leaching of important macro nutrients, e.g., phosphorus. Moreover, the examination of the relative importance of sexual and asexual reproduction within both disturbance types revealed that substrate changes occurring within anthropogenically-disturbed habitat actually have the potential to alter the natural demography of *S. jejuna* by limiting the plants ability to reproduce clonally.

The lack of fine particle sized substrates on disturbed sites is thought to be the main limitation to clonal growth as adventitious roots produced on lateral branches cannot establish in coarse sediments. Research also indicated a slight increase in reproduction by seed within populations resident on anthropogenically-disturbed habitat and that populations resident on anthropogenically-disturbed habitat were younger than natural populations. Populations of *S. jejuna* were also much younger than other similar arctic-alpine *Salix* species; it is thought that this may be a function of the unique clonal growth pattern.

It is important to note that under natural conditions increased recruitment has the ability to benefit the long term survival of a species by providing a means to adapt to changing environments and a greater genetic diversity. However, as clonal reproduction appears to be the main method of population sustainability within most natural populations, recovery planners must consider that clonal growth has allowed this species to persist in this harsh, arctic-like climate. Recovery plans should therefore focus on ensuring high adult survival, such as the complete elimination of off-road vehicle use throughout the limestone barrens habitat.

It is recommended that *in situ* conservation plans for this species be directed at restoring the natural ecological processes within anthropogenically-disturbed habitats by working towards a model that reflects adjacent undisturbed natural habitats. Rehabilitation may require the addition of fine textured sediments to improve moisture retention, substrate manipulation and the removal of all compaction sources such as off-road vehicle use. Restorative efforts should also consider the species preferences highlighted in this work. The continuation of long term demographic monitoring is essential to evaluate whether restorative efforts have promoted the clonal reproductive traits of natural populations.

This research acts as a template for all recovery actions on the limestone barrens and details vital information for accurate critical habitat delineation for *S. jejuna*. It also suggests that conservation plans that address woody clonal species need to consider that demographic parameters and life history traits may vary when populations are exposed to anthropogenic disturbance. Therefore, species recovery may be dependent upon the ability of recovery planners to address these differences in short and long term recovery planning.

APPENDIX I: Broad approaches to meet the recovery objectives for *S. jejuna* as outlined in the Recovery Strategy for the Barrens Willow (*Salix jejuna* Fernald) (Djan-Chékar et al. 2003). The associated recovery objectives are listed on page 6 of this document.

Table AI.I Approaches to meet recovery objectives for *S. jejuna*.

Priority	Objectives	Actions
Urgent	1, 2 and 3	Biological surveys
Urgent	1, 2 and 3	Habitat protection
Urgent	1	Monitoring
Necessary	1	Demographic research
Necessary	1 and 3	Taxonomic research
Necessary	1, 2, 3 and 4	Ecological research
Necessary	4	Public outreach
Necessary	1, 2 and 3	Compliance to regulations
Beneficial	1	Genetic research
Beneficial	1 and 4	*Ex situ* conservation
Beneficial	3 and 4	Restoration

APPENDIX II: Vascular plant ground coverage on *S. jejuna* study sites

Table AII.I Mean (SE) total ground area covered by vascular plant species for naturally- (n=5) and anthropogenically-disturbed (n=3) *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n= number of plots)

	Natural						Disturbed			
Species	**BHN-N** n=40	**BK1-N** n=47	**BK39-N** n=41	**CNA-N** n=83	**CNC-N** n=41	**MEAN (±SE)**	**BKD-D** n=24	**CND-D** n=80	**CNE-D** n=33	**MEAN (±SE)**
Achillea millefolium	0.00 (0.00)	0.06 (0.05)	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	**0.01 (0.01)**	0.08 (0.08)	0.04 (0.02)	0.03 (0.03)	**0.05 (0.15)**
Anemone parviflora	0.00 (0.00)	0.04 (0.03)	0.12 (0.05)	0.12 (0.04)	0.41 (0.08)	**0.14 (0.07)**	0.08 (0.08)	0.00 (0.00)	0.06 (0.04)	**0.05 (0.02)**
Angelica atropurpurea	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.04 (0.04)	0.01 (0.01)	0.03 (0.03)	**0.03 (0.01)**
Antennaria alpina	0.00 (0.00)	0.00 (0.00)	0.17 (0.06)	0.00 (0.00)	0.10 (0.05)	**0.05 (0.03)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Antennaria eucosma	0.00 (0.00)	0.02 (0.02)	0.17 (0.06)	0.00 (0.00)	0.00 (0.00)	**(0.04) (0.03)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Arctostaphylos uva-ursi	0.25 (0.25)	1.06 (1.06)	0.05 (0.03)	0.00 (0.00)	0.00 (0.00)	**0.03 (0.20)**	0.67 (0.62)	0.00 (0.00)	0.30 (0.30)	**0.32 (0.19)**
Armeria maritime	0.18 (0.06)	0.06 (0.04)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	**0.05 (0.03)**	0.00 (0.00)	0.01 (0.01)	0.03 (0.03)	**0.01 (0.01)**
Betula pumila	0.00 (0.00)	2.13 (1.43)	0.00 (0.00)	0.00 (0.00)	0.05 (0.05)	**0.44 (0.42)**	1.04 (1.04)	0.00 (0.00)	0.67 (0.48)	**0.57 (0.30)**
Braya fernaldii	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**(0.00) (0.00)**
Campanula rotundifolia	0.28 (0.07)	0.28 (0.10)	0.49 (0.08)	0.33 (0.05)	0.20 (0.06)	**0.32 (0.05)**	0.17 (0.10)	0.25 (0.05)	0.33 (0.10)	**0.25 (0.05)**
Carex spp.	0.43 (0.18)	1.00 (0.41)	1.24 (0.10)	0.08 (0.04)	0.00 (0.00)	**0.55 (0.25)**	0.25 (0.11)	0.00 (0.00)	2.06 (1.53)	**0.77 (0.65)**
Cerastium alpinum	0.03 (0.03)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**	0.00 (0.00)	0.04 (0.02)	0.00 (0.00)	**0.01 (0.01)**
Conioselinum chinense	0.00 (0.00)	0.11 (0.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.22 (0.02)**	0.08 (0.08)	0.06 (0.03)	0.39 (0.11)	**0.18 (0.11)**
Dasiphora fruticosa	0.00 (0.00)	0.00 (0.00)	0.49 (0.25)	0.05 (0.02)	0.59 (0.25)	**0.23 (0.13)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Dryas integrifolia	1.13 (0.68)	0.96 (0.60)	8.90 (1.54)	4.54 (0.74)	4.93 (1.03)	**4.10 (1.46)**	11.04 (4.43)	0.00 (0.00)	4.24 (1.94)	**5.09 (3.21)**
Empetrum nigrum	4.98 (1.25)	7.87 (3.09)	4.29 (0.95)	0.06 (0.03)	0.00 (0.00)	**3.44 (1.52)**	7.08 (3.67)	0.00 (0.00)	11.42 (4.33)	**6.17 (3.33)**
Erigeron hyssopifolius	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.07 (0.04)	**0.01 (0.01)**	0.00 (0.00)	0.01 (0.01)	0.00 (0.00)	**0.00 (0.00)**
Equisetum scirpoides .	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**
Euphrasia spp.	0.03 (0.03)	0.00 (0.00)	0.07 (0.04)	0.00 (0.00)	0.02 (0.02)	**0.02 (0.01)**	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	**0.01 (0.01)**

Table AII.I (Continued) Mean (SE) total ground area covered by vascular plant species for naturally- (n=5) and anthropogenically-disturbed (n=3) *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n= number of plots)

	Natural						Disturbed			
Species	BHN-N n=40	BK1-N n=47	BK39-N n=41	CNA-N n=83	CNC-N n=41	MEAN (±SE)	BKD-D n=24	CND-D n=80	CNE-D n=33	MEAN (±SE)
Gentianopsis nesophila	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (o.00)**	0.00 (0.00)	0.08 (0.03)	0.03 (0.03)	**0.04 (0.02)**
Gentianella propinqua	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (00)**	0.00 (0.00)	0.04 (0.02)	0.00 (0.00)	**0.01 (0.01)**
Juniperus horizontalis	1.80 (1.52)	9.83 (3.44)	0.00 (0.00)	0.00 (0.00)	3.24 (1.62)	**2.97 (1.81)**	0.21 (0.21)	0.00 (0.00)	8.03 (3.90)	**2.75 (2.64)**
Lomatogonium rotatum	0.03 (0.03)	0.02 (0.02)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**	0.00 (0.00)	0.05 (0.02)	0.03 (0.03)	**0.03 (0.01)**
Minuartia rubella	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.03 (0.02)	0.00 (0.00)	**0.01 (0.01)**
Packera pauciflora	0.03 (0.03)	0.85 (0.14)	0.05 (0.03)	0.00 (0.00)	0.20 (0.06)	**0.23 (0.16)**	0.42 (0.12)	0.09 (0.04)	0.00 (0.00)	**0.17 (0.13)**
Parnassia parviflora	0.00 (0.00)	0.04 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**	0.04 (0.04)	0.06 (0.03)	0.00 (0.00)	**0.03 (0.02)**
Persicaria vivipara	0.05 (0.03)	0.79 (0.16)	0.05 (0.03)	0.02 (0.02)	0.00 (0.00)	**0.18 (0.15)**	0.13 (0.07)	0.00 (0.00)	0.24 (0.08)	**0.12 (0.07)**
Pinguicula vulgaris	0.00 (0.00)	0.02 (0.02)	0.00 (0.00)	0.05 (0.02)	0.07 (0.04)	**0.03 (0.08)**	0.04 (0.04)	0.01 (0.01)	0.18 (0.07)	**0.08 (0.05)**
Plantago maritime	1.05 (0.16)	1.00 (0.14)	0.17 (0.06)	0.37 (0.07)	0.32 (0.10)	**0.58 (0.18)**	0.75 (0.09)	0.65 (0.09)	0.88 (0.14)	**0.76 (0.07)**
Poa spp.	0.73 (0.28)	1.57 (0.49)	1.59 (0.15)	0.80 (0.23)	0.24 (0.13)	**0.99 (0.26)**	0.79 (0.13)	0.01 (0.01)	1.82 (0.65)	**0.87 (0.52)**
Primula laurentiana	0.00 (0.00)	0.04 (0.04)	0.05 (0.03)	0.01 (0.01)	0.00 (0.00)	**0.02 (0.01)**	0.13 (0.07)	0.05 (0.02)	0.24 (0.08)	**0.14 (0.06)**
Primula mistassinica	0.03 (0.03)	0.00 (0.00)	0.05 (0.03)	0.00 (0.00)	0.00 (0.00)	**0.02 (0.01)**	0.00 (0.00)	0.00 (0.00)	0.03 (0.03)	**0.01 (0.01)**
Rhinanthus minor	0.08 (0.04)	0.06 (0.04)	0.02 (0.02)	0.00 (0.00)	0.02 (0.02)	**0.04 (0.01)**	0.00 (0.00)	0.01 (0.01)	0.03 (0.03)	**0.01 (0.01)**
Rhodiola rosea	0.48 (0.08)	1.15 (0.28)	0.37 (0.08)	0.58 (0.05)	0.27 (0.07)	**0.57 (0.15)**	0.54 (0.10)	0.16 (0.04)	0.09 (0.05)	**0.26 (0.14)**
Salix calcicola	5.90 (0.97)	0.66 (0.37)	0.00 (0.00)	0.00 (0.00)	0.10 (0.10)	**1.33 (1.15)**	0.33 (0.33)	0.06 (0.05)	0.09 (0.09)	**0.16 (0.09)**
Salix glauca	0.05 (0.05)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**	0.00 (0.00)	0.00 (0.00)	0.85 (0.49)	**0.28 (0.28)**
Salix jejuna	1.03 (0.18)	2.89 (0.45)	0.71 (0.08)	1.16 (0.22)	0.63 (0.10)	**1.28 (0.18)**	2.04 (0.64)	1.11 (0.23)	3.88 (0.68)	**2.34 (0.81)**
Salix reticulata	0.68 (0.39)	4.43 (0.71)	1.22 (0.10)	0.30 (0.05)	0.63 (0.17)	**1.45 (0.76)**	1.50 (0.54)	0.25 (0.05)	0.21 (0.07)	**0.65 (0.42)**

Table AII.I (Continued) Mean (SE) total ground area covered by vascular plant species for naturally- (n=5) and anthropogenically-disturbed (n=3) *S. jejuna* study sites on the limestone barrens of Newfoundland (Canada); July 2006 & 2007; (n= number of plots)

	Natural						**Disturbed**			
Species	**BHN-N** n=40	**BK1-N** n=47	**BK39-N** n=41	**CNA-N** n=83	**CNC-N** n=41	**MEAN (±SE)**	**BKD-D** n=24	**CND-D** n=80	**CNE-D** n=33	**MEAN (±SE)**
Salix uva-ursi	3.40 (1.38)	1.55 (0.69)	0.37 (0.08)	0.31 (0.10)	0.37 (0.11)	**1.20 (0.60)**	1.17 (0.25)	0.94 (0.27)	0.24 (0.10)	**0.78 (0.28)**
Salix vestita	0.88 (0.76)	9.47 (3.03)	0.00 (0.00)	0.00 (0.00)	0.15 (0.12)	**2.10 (1.85)**	0.00 (0.00)	0.00 (0.00)	3.94 (1.55)	**1.31 (1.31)**
Saxifraga aizoides	0.00 (0.00)	0.00 (0.00)	0.12 (0.05)	0.00 (0.00)	0.02 (0.02)	**0.03 (0.02)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Saxifrage oppositifolia	0.08 (0.04)	0.06 (0.04)	0.71 (0.11)	0.00 (0.00)	0.02 (0.02)	**0.17 (0.13)**	0.04 (0.04)	0.29 (0.06)	0.91 (0.19)	**0.41 (0.26)**
Silene acaulis	1.10 (0.53)	0.09 (0.06)	0.07 (0.05)	0.00 (0.00)	0.00 (0.00)	**0.25 (0.21)**	0.13 (0.09)	0.00 (0.00)	0.00 (0.00)	**0.04 (0.04)**
Solidago multiradata	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.04 (0.02)	0.22 (0.09)	**0.05 (0.04)**	0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.01)**
Tanacetum bipinnatum	0.00 (0.00)	0.19 (0.06)	0.05 (0.03)	0.00 (0.00)	0.00 (0.00)	**0.05 (0.04)**	0.00 (0.00)	0.14 (0.04)	0.03 (0.03)	**0.06 (0.04)**
Taraxacum ceratophorum	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.65 (0.08)	0.00 (0.00)	**0.22 (0.22)**
Thalictrum alpinum	0.00 (0.00)	0.17 (0.11)	0.29 (0.07)	0.01 (0.01)	0.20 (0.06)	**0.13 (0.06)**	0.13 (0.07)	0.00 (0.00)	0.00 (0.00)	**0.04 (0.04)**
Tofieldia glutinosa	0.00 (0.00)	0.00 (0.00)	0.02 (0.02)	0.05 (0.02)	0.05 (0.03)	**0.02 (0.01)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Viola nephrophylla	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**
Total vascular plant cover	26.80	62.62	22.63	9.02	24.90	**29.19 (8.92)**	32.83	5.13	43.82	**27.26 (11.51)**

* present on site but at very low abundances (account for less than 0.01% mean site coverage)

APPENDIX III: Age determination within naturally- and anthropogenically-disturbed populations of *S. jejuna*

Introduction

The determination of adult longevity and population age structure has numerous applications to conservation planning. Through this work, effective conservation strategies can be developed by gaining a better understanding of the influence of habitat quality on plant age. Aging distribution data is also important when examining reproductive parameters such as seed set, natural seedling recruitment and clonal growth. Lastly, aging distribution data also plays an important part when determining projected species persistence using population viability analysis.

Methods

Plants (N=114) of various stem diameters were randomly sampled (under appropriate permits), at a distance of at least 1m apart, within six study sites; CND-D, BHD-D, BK1-N and BK39- N in September 2005 and CNE-D and CNC-N in May 2007. Plants were cut with a fine saw just above the root collar, unless plants were marked for excavation, in which case the entire plant was removed. Samples were stored in small paper bags until processing.

A cross section of the main root collar complex for each sample was taken using a fine blade hand saw. A series of sand papers (200 -1200 grit) was used to prepare the sample surface. Due to low growth rates in many individuals, annual growth rings were examined under a stereomicroscope (40X) with fibre optic lighting. Distilled water was applied to samples to enhance viewing. To increase accuracy, growth rings were counted on at least 2 radii of the stem. If the number of rings differed between radii the average of the two radii was used. The age of plants collected in May 2007 was subtracted by 1 year to account for growth in 2006 and allow for comparison among sites. This assumption could be made as other arctic-alpine *Salix* have been shown to produce one growth ring per year. Of the 114 specimens collected 9 could not be aged due to distorted rings (N=3), rotten wood (N=5) and lack of defined rings (N=1).

Results

The age of the plants ranged from 5 to 40 years. Median ages varied significantly among sites (H = 11.33, df = 5, p = 0.045), ranging from 9 years (BHD-D) to 15.5 years (BK1-N). Plant age varied between disturbance types with naturally-disturbed sites having older plants than anthropogenically-disturbed sites ($F_{1,4}$=7.92, p=0.006). Using pooled data, there was a significant correlation between plant age and diameter of stem (r=0.401, p <0.001).

Table AIII.I A comparison of *S. jejuna* ages within selected study sites (N= natural and D= disturbed) on the limestone barrens of Newfoundland (Canada)

Site	**N**	**Mean Age (± S.E)**	**Median Age**
NATURAL			
BK1-N	20	15.9 (± 1.8)	15.5
BK39-N	19	13.2 (± 1.0)	14
CNC-N	10	16.2 (± 2.2)	15
Mean		**14.9 (± 0.9)**	**14.4**
DISTURBED			
BHD-D*	19	10.4 (± 0.9)	9
CND-D	19	11.0 (± 1.1)	10
CNE-D	18	13.8 (± 1.5)	12.5
Mean		11.7 (± 0.7)	10.2
TOTAL	105	**13.2 (± 0.6)**	**12.0**

* site only used for purpose of aging, no demographic information available

APPENDIX IV: Preliminary genetic testing of *S. jejuna* using starch gel electrophoresis

Introduction

Gaining an understanding of the genetic diversity within and among wild populations of *S. jejuna* provides insight into the primary modes of reproduction and allows for the determination of hybridization levels within populations. Further, genetic information allows recovery planners to accurately assess levels of clonal growth within all populations, which may have significant impact on the demographic structure and species persistence.

Additionally, through the development of genetic markers, delineation of species boundaries and species recognition are improved as *in situ* identification can be difficult. The ability to test the genetic diversity of populations will also ensure that a representative *ex situ* population is maintained.

Methods

Cuttings were collected from 15 randomly selected plants in the field in June 2005 and September 2006. Four naturally-disturbed (BK1-N, BHN-N, CNA-N, CNC-N) populations and one anthropogenically-disturbed (CND-D) population were involved in the genetic testing. Cuttings were transported to the Memorial University of Newfoundland Botanical Garden where they were transplanted to alpine soil mix and placed under a mister for one week to encourage root development. Cuttings were stored outside during the winter and were transferred to a cold house in the spring of 2007. To increase bud formation, cuttings were transferred to a greenhouse when buds were present on at least 50% of the cutting collection.

Genetic testing commenced in June 2007. Testing was conducted on both young and old leaves to assess whether leaf age affected the resolution of enzyme systems. Leaves were tested at 1 week, 3 week and 6 week intervals. Testing showed no differences between both old and new leaves. Plants were placed in a growth chamber 1 week prior to testing to ensure testing was carried out under the same environmental conditions. Preliminary testing revealed that tissue cultured material provided the most clear enzyme resolution.

As no previous genetic research had been conducted on *S. jejuna*, screening for enzyme resolution and variability was carried out using starch gel electrophoresis with 12 enzyme (Table AIV.I) systems and six buffer systems (Table AIV.II).

Table AIV.I Enzymes investigated in the electrophoretic testing of *S. jejuna*.
E.C No = Enzyme Commission Number

Enzyme	Abbreviation	E.C. No
Aconitase	ACO	4.2.1.3.
Alcohol dehydrogenase	ADH	1.1.1.1.
Glutamate dehydrogenase	GDH	1.4.1.2.
Glutamate oxaloacetate transaminase	GOT	2.6.1.1.
Isocitrate dehydrogenase	IDH	1.1.1.42.
Leucine aminopeptidase	LAP	3.4.11.1.
Phosphoglucomutase	PGM	2.7.5.1.
6-Phosphogluconate dehydrogenase	6-PGD	1.1.1.44.
Phosphogluconate isomerase	PGI	5.3.1.9.
Shikimate dehyrogenase	SDH	1.1.1.25.
Hekokinase	HE (HK)	2.7.1.1
Malic	ME	1.1.1.40.

Table AIV.II. Buffer systems used in the electrophoretic testing (enzyme screening) of *S. jejuna*

Designation	Electrode Buffer	Gel Buffer
A[1]	0.223 M Tris, 0.086 M Citric acid NaOH to pH 7.5	0.008 M Tris O.003 M Citric acid; Dilute 35 ml of electrode buffer in 1 litre, pH 7.5
B[1]	0.001 M NaOH 0.300 M Boric acid pH 8.6	0.015 M Tris 0.004 M Citric acid pH 7.8
C[1]	0.038 M LiOH 0.188 M Boric acid Adjust to pH 8.3 with dry components	0.045 M Tris 0.007 M Citric acid 1.0 M NaOH to pH 8.3
D[2]	0.3 M Boric acid 0.06 M LiOH Adjust to pH 8.1	0.005 M Citric acid 0.0315 M Tris 10% Electrode buffer Adjust to pH 8.5
E[2]	0.223 M Tris 0.094 M Citric acid Adjust to pH 6.3	0.13 M Tris 0.043 M Citric acid Adjust to pH 7.0
F[2]	0.19 M Boric acid 0.04 M LiOH Adjust to pH 8.3	0.05 M Tris 0.007 M Citric acid Adjust to pH 8.3

Source of buffer systems:

[1] Soltis DE, Haufler CH, Darrow DC, Gastony GJ (1983) Starch gel electrophoresis of ferns: A compilation of grinding buffers, gel and electrode buffers, and staining schedules. American Fern Journal 73: 9-27

[2] Aravanopoulos FA, Zsuffa L,Chong KX (1993) The genetic basis of enzymatic variation in *Salix exigua*. Hereditas 119:77-88

Results

Three enzymes systems were identified on buffer system D (Table AIV.II); 6-PGD, PGI, and ADH. All enzymes were repeatable however only PGI consistently provided clear, repeatable results. In total, 55 individual plants were tested from five populations. All individuals were monomorphic for PGI 1 and ten different phenotypes were resolved among the 55 individuals assayed for PGI 2. The number of phenotypes identified within each population varied from 3 to 7.

Unexpectedly, populations with a higher degree of clonal growth (BK1-N, CNA-N) expressed a larger number of phenotypes. A comparison between naturally- and anthropogenically-disturbed populations could not be made due to the lack of anthropogenically-disturbed populations sampled. Cuttings were established from plants collected during the aging experiment (Appendix IV) at two additional disturbed sites but did not survive due to sawfly infestation.

Table AIV.III Expression of PGI 2 during electrophoretic testing of *S. jejuna*; N = number of individual plants tested within each population.

Site	N	Number of phenotypes expressed
BK1-N	14	7
BHN-N	7	3
CND-D	12	5
CNC-N	12	3
CNA-N	10	7

APPENDIX V: Morphological data for *S. jejuna*

Introduction

Field observations show that the morphology of *S. jejuna* varies within populations and across its range. Geographical distribution, habitat structure, hybridization, and anthropogenic disturbance may influence the expression of physical traits among populations. Data on numerous morphological characteristics were collected with the intention of providing a better understanding of the cause of this variation and to improve species recognition. Population means (± SE) for each morphological trait are displayed in Table AV.I.

Methods

Morphological characteristics were measured for *S. jejuna* encountered on both naturally- (N) and anthropogenically- (D) disturbed study sites during plot sampling in July and August, 2006. In Table AV.II, location is the cell position within the 1m^2 plot. The morphological features measured included; Sex (1= vegetative (unknown), 2= female, 3= male; BD (basal diameter of root collar to the nearest 0.01 mm using digital calliper); L (length of individual plant in mm); W (width of individual plant in mm); LB (length of longest branch in mm, from start of branch at root collar complex to terminal bud); and # Branches (number of branches on root collar complex, includes only main branches). If information is missing in Table AV.II it indicates these features were not clearly visible or were difficult to determine at the time of sampling.

Results

Table AV.I Morphological characteristics (mean ± SE) of *S. jejuna*, compared between naturally- and anthropogenically-disturbed study sites; limestone barrens of Newfoundland (Canada); July 2006

Site	# Plants sampled	Basal Diameter (mm)	Length of Individual Plant (mm)	Width of Individual Plant (mm)	Length of Longest Branch (mm)	# Branches Per Plant
NATURAL						
BHN-N	113	4.9 ± 0.2	78.8 ± 5.4	42.0 ± 2.8	62.6 ± 3.8	2.3 ± 0.1
BK39-N	108	3.1 ± 0.1	35.5 ± 2.3	14.1 ± 0.9	33.1 ± 3.0	1.4 ± 0.1
BK1-N	215	4.6 ± 0.2	61.2 ± 3.4	35.3 ± 2.2	43.5 ± 2.5	2.5 ± 0.1
CNA-N	206	3.8 ± 0.2	55.5 ± 3.3	30.7 ± 2.0	33.8 ± 1.7	2.5 ± 0.1
CNC-N	67	3.7 ± 0.4	44.2 ± 5.9	22.0 ± 2.7	31.6 ± 4.4	1.9 ± 0.1
Mean		**4.1 ± 0.1**	**55.5 ± 1.8**	**29.6 ± 1.0**	**41.0 ± 1.3**	**2.1 ± 0.0**
DISTURBED						
BKD-D	159	3.2 ± 0.2	30.9 ± 1.8	16.5 ± 1.0	25.4 ± 1.6	2.0 ± 0.1
CND-D	198	5.1 ± 0.3	70.4 ± 4.5	38.0 ± 2.7	45.9 ± 2.9	2.4 ± 0.1
CNE-D	357	7.2 ± 0.3	61.6 ± 2.9	36.9 ± 1.6	42.2 ± 1.9	2.6 ± 0.1
Mean		**5.7 ± 0.2**	**56.9 ± 2.0**	**32.5 ± 1.1**	**39.5 ± 1.3**	**2.4 ± 0.0**

Notes: BHN-N has plants with much larger morphological traits compared to other natural sites. It is thought that the variation expressed at BHN-N is due to the hybridization of *S. jejuna* with *S. calcicola* as plants at BHN-N had larger catkins and flowered earlier than other sites.

Table AV.II Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	1	10G6	1	15.13	348.70	308.06	141.64	6
BK1-N	1	10H6	1	7.05	126.02	85.68	71.95	3
BK1-N	1	10H4	1	20.92	132.59	82.67	61.42	5
BK1-N	1	10H3	1	12.74	154.13	99.24	90.13	5
BK1-N	1	10B7	1	3.26	32.25	19.95	24.50	2
BK1-N	2	12G10	1	1.99	19.13	16.87	7.92	4
BK1-N	2	12H10	1	5.54	52.37	61.15	44.47	2
BK1-N	2	12C9	1	8.45	113.15	67.95	89.89	2
BK1-N	2	12H7	1	14.48	133.27	110.35	133.27	2
BK1-N	2	12J6	1	5.74	21.64	15.24		0
BK1-N	2	12J4	2	19.52	308.98	259.04		
BK1-N	2	12I4	1	3.08	26.78	15.64	12.34	2
BK1-N	2	12D4	2	5.52	174.51	76.07	122.73	4
BK1-N	3	14C10	1	4.50	124.70	64.60	92.65	4
BK1-N	3	14A9	1	2.90	123.70	46.80	72.80	2
BK1-N	3	14G7	2	7.03	195.80	46.19	102.38	5
BK1-N	3	14F5	1	13.56	150.60	84.33	150.60	2
BK1-N	3	14A5	2	9.35	196.18	90.35	115.45	4
BK1-N	3	14F4	1	4.10	43.56	70.28	88.35	3
BK1-N	3	14I4	1	6.20	63.25	36.14		0
BK1-N	3	14I3	2	6.20	123.47	62.24	76.30	2
BK1-N	4	16B10	1	5.20	65.26	41.16	41.15	3
BK1-N	4	16H10	1	3.10	88.35	38.15	32.13	2
BK1-N	4	16I10-1	1	3.15	34.14	18.07	19.08	2
BK1-N	4	16I10-2	1	2.00	11.40	9.30		0
BK1-N	4	16I10-3	1	4.20	43.17	34.13	36.14	4
BK1-N	4	16I9	1	7.30	63.25	15.60	63.25	4
BK1-N	4	16H9	1	2.10	33.13	21.80	33.13	2
BK1-N	4	16 E9	1	14.50	102.40	50.20	47.19	5
BK1-N	4	16B9	1	1.00	3.00	3.00		0
BK1-N	4	16C8	2	3.10	74.29	44.18	74.29	3
BK1-N	4	16G81	1	1.00	4.10	3.00		0
BK1-N	4	16G82	1	1.00	4.20	2.00		0
BK1-N	4	16I8	2	8.30	123.48	62.00	79.31	4
BK1-N	4	16I7	1	1.00	4.00	2.00		0
BK1-N	4	16F7	1	8.30	27.11	14.50		0
BK1-N	4	16 E7	1	1.00	16.00	9.30	6.20	2
BK1-N	4	16 C7	1	12.50	113.45	55.20	57.23	2
BK1-N	4	16 E6	1	1.00	7.00	4.00		0
BK1-N	4	16I5	1		15.60	10.40		0
BK1-N	4	16F5	1	4.00	31.12	14.50	31.12	1
BK1-N	4	16C4	1	19.70	142.56	112.44	142.56	6

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	4	16F3	1	2.00	28.12	14.56	20.80	2
BK1-N	4	16 E3	1	1.00	3.10	2.00		0
BK1-N	4	16B2	1	6.20	23.90	15.50		0
BK1-N	4	16D2	1	1.00	7.00	5.20	7.00	2
BK1-N	4	16 E2	1	8.30	88.35	35.40	45.18	4
BK1-N	4	16G1	1	1.00	5.20	4.00		0
BK1-N	4	16B1	1	2.00	14.50	13.40	14.50	2
BK1-N	5	18B10	1	5.83	30.98	16.90	31.47	2
BK1-N	5	18F10	1	5.75	37.53	23.37	36.61	3
BK1-N	5	18I9	2	9.17	121.59	92.22	41.26	3
BK1-N	5	18B8	1	1.93	34.58	37.94	29.19	2
BK1-N	5	18F7	1	1.02	5.91	3.68		0
BK1-N	5	18E6	1	10.97	153.58	140.69	153.58	6
BK1-N	5	18F5	1	3.42	26.53	16.16	14.00	4
BK1-N	5	18B3	1	9.24	28.58	19.21	16.12	3
BK1-N	5	18I3	1	8.62	119.17	60.86	119.17	1
BK1-N	5	18B2	2		223.79	126.68		
BK1-N	5	18C1	1	4.17	144.54	54.10	56.47	3
BK1-N	6	110D8	1	0.91	16.42	12.52	9.90	2
BK1-N	6	110B6	2	11.70	256.56	34.59		0
BK1-N	6	110D6	1	4.43	36.45	21.77	19.36	3
BK1-N	6	110J6	1	1.11	10.99	7.03		
BK1-N	6	110I5	1		17.51	9.79		
BK1-N	6	110B4	1	3.60	52.72	31.24	23.16	3
BK1-N	6	110 E4	2	4.67	69.83	42.58		0
BK1-N	6	110G4	1	5.78	31.96	21.61	15.22	3
BK1-N	6	110J4	1	3.55	79.36	63.73	46.45	4
BK1-N	6	110H3	1	0.48	6.84	3.55		0
BK1-N	6	110G3	1	0.67	6.50	4.87	6.38	2
BK1-N	6	110D2	1	1.85	19.95	11.01	8.89	3
BK1-N	6	110H2	1	2.94	25.72	22.96	15.76	4
BK1-N	6	110C1	1	8.53	81.56	50.86		0
BK1-N	7	112D10	1	4.81	75.91	37.74	75.98	2
BK1-N	7	112G10	1		153.90	66.88		
BK1-N	7	112J9	1	0.67	6.55	4.83		0
BK1-N	7	112H9	1	3.19	33.85	23.30	19.23	2
BK1-N	7	112A9	1	9.66	78.33	34.48	61.33	5
BK1-N	7	112F8	1	8.38	136.62	63.13		0
BK1-N	7	112I7	1	1.46	13.97	4.80	2.57	2
BK1-N	7	112B7	1	4.58	28.07	18.84	14.59	2
BK1-N	7	112A6	1	7.37	49.36	24.62	23.08	3
BK1-N	7	112B6	1	2.12	18.59	18.29	12.49	2
BK1-N	7	112F6	1		40.91	29.60		
BK1-N	7	112I5	1	1.25	39.12	23.08	18.44	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	7	112 E5	1	1.20	13.46	5.28	7.38	3
BK1-N	7	112B3	1	9.77	153.88	87.61	88.95	3
BK1-N	7	112 E3	1	4.31	237.65	59.13	119.57	2
BK1-N	7	112F1	1	0.76	3.45	3.12		0
BK1-N	7	112 E1	1	5.62	59.44	37.80	43.19	2
BK1-N	8	114G10	1	1.24	28.12	16.04	16.15	2
BK1-N	8	114I10	1	4.40	23.69	12.63	12.27	4
BK1-N	8	114J91	1	1.80	9.23	8.45	6.07	2
BK1-N	8	114J92	1	5.24	45.54	23.52		0
BK1-N	8	114F9	1	2.81	23.36	13.47	8.57	3
BK1-N	8	114D9	1	1.00	2.26	1.41		0
BK1-N	8	114 E8	1	5.61	106.46	27.08	36.22	2
BK1-N	8	114F7	1	0.95	7.54	8.59	4.21	2
BK1-N	8	114D7	1	0.81	30.00	17.25	15.30	3
BK1-N	8	114A7	1	0.70	9.02	5.95	3.14	2
BK1-N	8	114C6	1		10.82	5.71		
BK1-N	8	114F6	1	3.41	14.14	10.03	6.81	3
BK1-N	8	114H5	1	7.23	55.43	27.80	27.50	4
BK1-N	8	114C5	1	2.29	14.79	9.36	9.55	2
BK1-N	8	114C3	1	2.31	108.75	41.48	46.98	2
BK1-N	8	114A3	1	0.44	8.87	5.85	8.87	1
BK1-N	8	114H2	1	0.67	37.49	12.04	37.49	1
BK1-N	8	114 E1 1	1	1.50	14.39	10.13	10.73	3
BK1-N	8	114 E1 2	1	1.09	12.65	6.97	12.65	1
BK1-N	8	114 E1 3	1	3.60	19.25	10.24		0
BK1-N	9	116G10	1	1.31	6.32	3.39		0
BK1-N	9	116I10	1		42.18	17.70		
BK1-N	9	116J101	1	4.78	69.44	31.10	37.24	3
BK1-N	9	116J102	1	0.77	7.23	3.38		0
BK1-N	9	116I9	1	3.54	92.43	39.74	72.74	2
BK1-N	9	116C8	1	1.27	43.93	23.21		0
BK1-N	9	116 E8	1	0.86	7.83	6.94		0
BK1-N	9	116F8	1	2.01	35.18	16.32	16.35	2
BK1-N	9	116G8	1	0.99	29.56	13.01	9.28	3
BK1-N	9	116H7	1	1.67	59.87	36.47	32.27	3
BK1-N	9	116D7	1	2.24	36.45	14.23	22.98	3
BK1-N	9	116C6	2		112.77	56.76		
BK1-N	9	116J6	1	0.46	6.31	2.93	3.82	2
BK1-N	9	116I5	1	0.89	10.93	3.88	9.76	1
BK1-N	9	116G5	1	3.82	40.26	35.30	14.87	3
BK1-N	9	116B4	1	9.14	103.93	73.54	47.30	2
BK1-N	9	116B3	1	3.46	63.42	33.33	35.87	3
BK1-N	9	116 E1	1	3.11	19.55	10.83	8.86	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	9	116C1	1	2.87	20.57	12.22	11.06	2
BK1-N	9	116I3	2	12.57	225.24	104.57	225.24	5
BK1-N	10	118D10	2	4.68	198.18	122.99	97.07	4
BK1-N	10	118G10	1	2.27	65.55	38.63		0
BK1-N	10	118C9	1	5.83	88.84	63.78		0
BK1-N	10	118A9	1		80.39	47.63		
BK1-N	10	118H7	1	6.76	74.39	50.05	31.19	3
BK1-N	10	118 E7	1	3.08	45.65	33.45	45.65	1
BK1-N	10	118 E6	1	6.55	41.82	32.23	21.27	2
BK1-N	10	118H6	1	5.90	59.68	37.97	42.60	2
BK1-N	10	118G5	1		5.46	4.27		0
BK1-N	10	118D5	1	1.88	79.89	32.84	46.47	2
BK1-N	10	118C41	1	5.56	105.46	64.12	105.46	4
BK1-N	10	118 C42	1	6.20	36.16	18.69	22.33	1
BK1-N	10	118 E4	1	11.33	34.44	21.06		0
BK1-N	10	118G3	1	4.31	46.73	20.37	46.73	1
BK1-N	10	118B2 1	1	2.74	42.00	21.81	28.17	4
BK1-N	10	18B22	1	3.73	20.60	12.51	20.60	3
BK1-N	10	118C2	1	3.49	34.47	16.46	18.34	3
BK1-N	10	118I1	1	2.44	19.31	10.21	19.31	1
BK1-N	11	30B10	1	2.04	34.35	16.24	34.35	1
BK1-N	11	30 E9	1	3.74	81.83	47.78	81.83	2
BK1-N	11	30D8	1	8.16	168.61	100.14	78.17	4
BK1-N	11	30G8	1	0.54	3.39	2.07		0
BK1-N	11	30C6	1	1.93	12.97	7.13	8.26	2
BK1-N	11	30H3	1	2.37	80.96	24.63	80.96	1
BK1-N	11	30 E2	1	0.76	10.10	7.76	8.15	2
BK1-N	12	32B10	1	12.12	130.80	122.19	59.79	5
BK1-N	12	32D10	1	3.32	14.96	9.12	9.88	1
BK1-N	12	32H10	1	2.15	6.88	3.59		0
BK1-N	12	32 E9	1		17.29	10.84		
BK1-N	12	32D8	1	0.93	6.10	3.33		0
BK1-N	12	32G6	1	2.04	9.88	5.64	9.88	1
BK1-N	12	32A3	2	3.57	74.90	43.51	23.92	2
BK1-N	12	32C3	1	5.59	41.41	15.77	41.41	1
BK1-N	13	34 E10	1	1.08	13.94	8.24	5.68	3
BK1-N	13	34G10	1	3.69	31.62	18.59	19.52	3
BK1-N	13	34J91	2	5.53	37.25	19.72	22.02	3
BK1-N	13	34J92	1	6.67	16.68	9.37	16.68	1
BK1-N	13	34H9	1	6.58	21.97	18.46		0
BK1-N	13	34F9	1	4.91	21.41	15.36	9.18	5
BK1-N	13	34B9	1	12.64	39.54	23.63	19.81	4
BK1-N	13	34A9	1	8.48	74.07	49.05	39.30	4
BK1-N	13	34C8	2	6.32	35.22	21.47	15.64	6

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	13	34F8	1	7.74	67.65	50.50	41.66	2
BK1-N	13	34G8	1	5.98	21.09	17.67	13.85	2
BK1-N	13	34J7	1	7.21	69.45	68.24	69.45	1
BK1-N	13	34F7	1	1.27	12.38	5.70	6.81	2
BK1-N	13	34F61	1	4.40	37.08	22.91	19.01	3
BK1-N	13	34F62	1	3.43	72.73	61.37		0
BK1-N	13	34A4	1	7.65	38.11	18.03	38.11	1
BK1-N	13	34F2	1	6.37	26.46	17.38		
BK1-N	14	36B101	1	8.40	66.42	42.06	31.75	3
BK1-N	14	36A102	1	3.47	27.32	14.88	11.71	2
BK1-N	14	36D9	2	7.27	95.00	49.37	84.27	3
BK1-N	14	36A91	1	2.10	17.02	11.90	17.02	2
BK1-N	14	36C7	1	0.94	17.41	16.23	10.63	2
BK1-N	15	38B8	1	7.84	122.46	60.46	122.46	5
BK1-N	15	38H8	1	1.37	42.44	24.88	33.65	2
BK1-N	15	38I8	2		127.53	41.06		
BK1-N	15	38H7	1	6.57	34.94	30.42	15.24	3
BK1-N	15	38C6	1	11.69	153.89	120.15	97.26	3
BK1-N	15	38H6	1	5.07	74.29	43.45	53.33	3
BK1-N	15	38B5	1	4.00	45.03	20.22	22.78	2
BK1-N	15	38B4	1	1.01	15.03	7.12	15.03	1
BK1-N	15	38C41	1	1.16	20.21	6.41	20.21	1
BK1-N	15	38C42	1	0.92	19.80	5.87	11.47	2
BK1-N	16	40A10	2	9.75	90.94	61.95	90.94	4
BK1-N	16	43F8	1	2.16	9.83	7.05	3.19	3
BK1-N	16	40J8	1	0.48	4.10	1.26		0
BK1-N	16	49B7	1	8.45	46.71	31.31		
BK1-N	16	40J5	1	9.05	97.96	72.29	55.54	3
BK1-N	17	42B41	1	1.06	40.29	19.58		
BK1-N	17	42B42	1			3.38		0
BK1-N	17	42I1	1	1.75	51.61	12.84	51.61	2
BK1-N	17	42F1	1	2.53	44.47	21.91	27.60	2
BK1-N	19	46 E10	1	5.51	48.88	33.41	48.88	1
BK1-N	18	44I9	2	9.04	53.86	33.83	53.86	3
BK1-N	18	44G9	1	1.02	7.93	4.27	4.65	2
BK1-N	18	44C6	1	12.88	124.25	88.77	47.89	4
BK1-N	18	44H8	1	0.61	5.39	3.01		0
BK1-N	18	44C7	1	8.44	28.89	14.41	15.48	2
BK1-N	18	44B4	1	0.84	8.39	5.77		0
BK1-N	18	44A6	1	1.26	23.73	15.71	23.73	1
BK1-N	19	46B6	2	7.22	55.40	46.44	39.41	3
BK1-N	19	46D6	1	4.77	60.11	43.05	27.35	3
BK1-N	19	46F6	1	1.05	15.92	8.92	10.29	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	19	46A5	1	8.37	56.64	55.55	30.32	5
BK1-N	19	46H3	1	3.86	30.16	17.64	15.34	2
BK1-N	19	410A10	1	2.13	32.28	19.84	32.28	1
BK1-N	22	410J10	1	3.53	34.27	31.69	34.27	2
BK1-N	22	410C9	1	3.83	29.08	20.55	14.04	2
BK1-N	22	410D8	2		148.93	45.98	81.84	4
BK1-N	22	410J9	1	6.63	79.79	52.01		0
BK1-N	22	410 E9	1	3.52	60.99	27.25	60.99	1
BK1-N	22	410B8	1	5.78	151.71	79.87	86.17	2
BK1-N	22	410 E8	1	4.97	76.21	26.82	76.21	1
BK1-N	22	412H7	1	0.78	12.88	6.04		0
BK1-N	22	412D7	1	2.61	110.54	56.14	110.54	3
BK1-N	22	412B7	1	5.85	113.20	65.94		0
BK1-N	22	412D6	1	5.61	105.82	47.59	68.81	4
BK1-N	22	412D5	1	7.63	116.98	58.75	80.73	3
BK1-N	23	414B5	1	4.46	87.84	43.83	70.09	2
BK1-N	23	414G9	1	0.42	3.66	0.92		0
BK1-N	23	414A9	1	8.99	123.62	68.11	44.50	2
BK1-N	23	414C8	1	1.23	9.21	7.37	9.21	1
BK1-N	23	414B5	1	8.05	58.61	35.36	58.61	1
BK1-N	23	414A4	1	0.72	7.67	9.45	7.67	1
BK1-N	24	416B41	1		19.60	13.50		
BK1-N	24	416B42	1	1.53	20.67	10.72		
BK1-N	24	416B2	1	9.97	51.18	17.26	40.73	2
BK1-N	24	416D2	1	0.96	4.35	6.16		0
BK1-N	24	416G1	1	3.88	22.83	16.08	18.89	3
BK1-N	24	416 E1	1	5.86	70.99	34.76	45.66	5
BK1-N	25	418B10	1	4.73	76.74	27.19	76.74	1
BK1-N	25	418C10	1	0.74	4.83	2.91		0
BK1-N	25	418D10	1	5.02	54.81	22.83	34.30	3
BK1-N	25	418F10	1	7.47	56.43	38.09	37.71	3
BK1-N	26	70J9	1	2.91	44.84	31.03	43.77	2
BK1-N	26	70H9	1	7.50	129.99	118.38	102.85	3
BK1-N	26	70D9	2	6.26	115.30	70.53	60.02	4
BK1-N	26	70H8	1	1.78	13.20	8.10	7.30	3
BK1-N	26	70I81	1	0.83	7.24	5.61		0
BK1-N	26	70I82	1	1.26	21.05	13.23	17.64	2
BK1-N	26	70H7	2	10.87	144.25	103.52	70.94	3
BK1-N	26	70D7	1		119.58	61.74		0
BK1-N	27	72A7	2	4.26	120.61	89.36	90.31	6
BK1-N	27	72A6	1	6.37	51.52	36.07	39.77	2
BK1-N	27	72B6	2	8.17	128.54	71.08		0
BK1-N	27	72D6	1	3.17	107.87	71.66		0
BK1-N	27	72G6	1	6.96	61.96	41.79	61.96	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK1-N	27	72H6	1	2.32	19.63	11.03	14.86	3
BK1-N	27	72I5	1	6.38	60.21	33.60	33.13	2
BK1-N	27	72G5	1	1.40	10.86	5.53	10.86	1
BK1-N	27	72B5	1	5.30	123.39	80.23	72.37	3
BK1-N	27	72A5	1	1.97	52.73	29.75		
BK1-N	27	72C3	1	1.44	16.52	8.22	14.28	2
BK1-N	27	72A2	1	6.03	123.20	40.69	68.14	2
BK1-N	27	72B2	1	7.17	90.87	56.92		
BK1-N	27	72G2	1	3.56	56.16	34.53	32.68	4
BK1-N	28	74A3	1	0.48	4.62	2.95		0
BK1-N	28	74B10	1	0.43	2.50	1.01		0
BK1-N	28	74C8	1			2.67		0
BK1-N	28	74F8	1	7.84	109.28	43.33	109.28	1
BK1-N	28	74F7	1	4.56	147.88	93.56	147.88	3
BK1-N	28	74J8	1	12.35	119.19	41.00	81.64	3
BK1-N	29	76J9	1	3.36	57.60	37.50	54.50	2
BK1-N	29	76B9	1	3.80	58.48	33.30		
BK1-N	29	76 E8	2	7.34	73.93	37.87	73.93	2
BK1-N	29	76I8	1	4.16	133.17	104.90		
BK1-N	29	76A7	1	2.46	17.77	10.09	17.77	1
BK1-N	29	76H6	1	6.85	105.17	60.06	105.17	2
BK1-N	29	76J6	2	4.37	201.05	153.82		0
BK1-N	30	78G4	1	3.90	85.47	36.28	32.81	3
BK1-N	30	78I4	1		109.89	65.60		
BK1-N	31	710 B7	1	1.07	6.79	3.09		
BK1-N	31	710G1	1	6.22	117.30	55.80	58.06	2
BK1-N	31	710 E9	1	1.50	50.68	30.41	26.50	2
BK1-N	32	712 E8	1	5.47	39.13	17.03	24.55	2
BK1-N	32	712G7	1	4.98	92.24	32.91		
BK1-N	32	712 E7	1	8.04	120.28	91.26		
BK1-N	32	712D5	1		11.37	6.04		
BK1-N	33	714I4	3	9.98	402.59	274.02		
BK1-N	33	714I2	1	5.23	110.40	51.04		
BK1-N	33	714D2	1	3.05	19.23	9.42	19.23	1
BK1-N	33	714A10	1	1.69	55.82	15.17	55.82	1
BK1-N	34	716B10	1	1.22	4.57	4.07		0
BK1-N	34	716J10	1	3.32	63.93	33.77	43.37	2
BK1-N	34	716A9	1	2.67	69.73	38.03	36.16	2
BK1-N	35	718I8	1	1.45	59.50	22.23	31.52	2
BK1-N	35	718J5	1	3.82	51.21	37.97		
BK1-N	35	718J2	1	8.41	50.50	24.39	50.50	2
BK1-N	35	718I10	1	1.98	8.98	6.25		
BK39N	1	10A7	1	3.71	28.09	11.96		

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK39N	1	10H5	1	3.95	41.07	17.29	23.01	2
BK39N	1	10F5	1	8.50	89.23	16.92	70.54	2
BK39N	1	10 E51	1	2.46	11.01	5.54		
BK39N	1	10 E52	1	1.18	9.31	3.55	4.69	1
BK39N	1	10D5	1	0.73	3.53	1.55		0
BK39N	1	10H4	1	9.29	153.04	22.15	86.20	3
BK39N	1	10G4	1	0.77	3.51	1.99		0
BK39N	1	10A3	1		48.70	33.04		
BK39N	1	10C2	1	1.05	5.74	3.49	4.07	1
BK39N	1	10H1	1	1.09	3.26	1.37		0
BK39N	1	10G1	1	3.40	19.12	8.14		
BK39N	1	10 E1	1	5.37	28.46	10.95	28.46	1
BK39N	1	10D11	1	1.24	4.54	3.67	4.37	2
BK39N	1	10D12	2	4.72	52.76	32.26	34.88	2
BK39N	1	10B1	1	0.78	1.76	2.18		0
BK39N	2	12I10	1	0.99	13.54	5.77	13.54	1
BK39N	2	12J10	1	4.70	13.31	9.04		
BK39N	2	12F9	1	2.48	15.64	5.39	15.64	1
BK39N	2	12 E9	1	4.07	67.36	24.87	24.20	2
BK39N	2	12C9	1	1.20	6.90	4.86		
BK39N	2	12C8	1	1.34	13.24	5.18		
BK39N	2	12 E8	1	0.60	3.25	1.58		0
BK39N	2	12G8	1	5.80	28.81	9.49	28.81	1
BK39N	2	12J7	1	2.33	61.52	4.56		0
BK39N	2	12F7	1	0.71	8.61	1.59		0
BK39N	2	12A7	1	2.22	4.99	3.76		
BK39N	2	12C6	1	0.56	2.23	1.05		0
BK39N	2	12D6	1	1.80	15.92	11.42	15.92	1
BK39N	2	12C2	1	3.49	16.73	12.29	13.01	2
BK39N	2	12G2	1	1.43	10.61	4.72		0
BK39N	3	14F6	1	0.68	3.58	2.91		0
BK39N	3	14J5	1	4.72	60.39	41.48	26.16	2
BK39N	3	14H4	1		10.47	3.34		
BK39N	3	14C4	1	2.45	17.80	10.57	9.21	3
BK39N	3	14A41	1	1.91	36.48	9.03		
BK39N	3	14A42	1	3.66	58.43	21.92	47.83	2
BK39N	3	14B3	1		3.75	1.60		0
BK39N	3	14 E3	1	1.49	13.06	4.38	13.06	1
BK39N	4	16I8	2	6.07	207.06	48.02	207.06	1
BK39N	4	16F7	2	5.57	62.92	26.34	62.92	1
BK39N	4	16C7	1	2.77	32.36	20.65		
BK39N	4	16C6	1	0.80	15.21	6.00	8.43	2
BK39N	4	16C5	1	4.52	57.91	36.00	43.97	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK39N	4	16D4	1	2.52	10.30	6.92	10.07	1
BK39N	4	16 E3	1	5.10	49.47	16.20		
BK39N	4	16 B1	1	5.12	61.88	24.69	45.43	2
BK39N	5	18B9	1	5.75	38.27	15.94	38.27	1
BK39N	5	18 E2	1	3.09	17.78	8.87		
BK39N	6	110D10	1	2.67	25.06	13.10	17.70	2
BK39N	6	110C5	2	7.94	194.31	97.58	194.31	2
BK39N	6	110G2	1	1.09	11.07	5.67	11.07	2
BK39N	7	112B8	1	2.63	15.20	9.71	11.22	2
BK39N	7	112D4	1	6.22	50.68	31.54	50.68	1
BK39N	7	112C4	1	4.25	32.54	20.87	17.33	2
BK39N	7	112A3	1	3.31	16.11	7.66		0
BK39N	7	112A1	1	4.71	67.12	17.28	48.26	3
BK39N	8	114E10	1	1.43	16.16	7.61	16.16	1
BK39N	9	116F10	1	3.68	21.66	12.14	12.75	2
BK39N	9	116G10	3	4.48	66.59	49.37	55.54	2
BK39N	9	116G9	1	5.49	110.14	23.31		0
BK39N	9	116A8	1	2.84	16.18	10.95	16.18	2
BK39N	9	116J7	1	2.03	27.11	15.60		
BK39N	9	116A6	1	2.68	46.11	26.18	16.73	2
BK39N	9	116I6	1	3.89	92.48	17.00		
BK39N	9	116C41	1	4.92	22.23	13.89	22.23	1
BK39N	9	116C42	1	5.24	24.16	13.33	22.63	1
BK39N	9	116G1	1	2.73	27.17	11.80		0
BK39N	10	118I9	1	1.28	21.56	7.92	21.56	1
BK39N	10	118F9	1	2.88	12.55	8.21	12.55	1
BK39N	10	118 E9	1	3.01	21.88	11.29		
BK39N	10	118C8	1	5.54	53.11	12.94	29.80	1
BK39N	10	118D8	1	2.31	10.51	5.82	5.65	2
BK39N	10	118J8	3	3.39	95.56	42.78	55.18	2
BK39N	10	118F6	1	1.66	9.32	6.21		
BK39N	10	118I5	1	3.28	15.35	7.89		
BK39N	10	118D3	1	2.66	39.02	10.23	14.02	1
BK39N	10	118D2	1	4.63	65.05	32.84	65.05	1
BK39N	11	30A10	1	1.67	16.13	10.36		
BK39N	11	30H71	1	0.63	7.57	3.15		0
BK39N	11	30H72	1	0.41	3.34	1.93		0
BK39N	11	30G7	1	0.70	3.55	1.85		0
BK39N	11	30B5	1	1.58	8.76	4.46		
BK39N	11	30 E4	1	4.25	78.25	16.89	43.02	1
BK39N	11	30C2	1	6.12	27.62	20.42		
BK39N	11	30 E2	1	2.87	22.65	6.86		
BK39N	11	30G1	1	1.02	15.67	8.47		

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK39N	12	32A101	1	0.98	12.85	5.93	6.63	2
BK39N	12	32A102	1	0.93	10.91	5.18	10.91	2
BK39N	12	32C10	1	3.49	25.88	9.79		
BK39N	12	32 E10	1	4.44	60.02	10.64	41.43	3
BK39N	12	32 E9	1	6.32	65.52	39.49	41.08	2
BK39N	12	32C8	1	2.11	65.63	18.39	65.63	2
BK39N	12	32 E8	1	7.53	45.99	17.27		
BK39N	12	32F8	1	9.05	28.70	19.77		
BK39N	12	32G8	1	2.54	29.25	11.10	29.25	2
BK39N	12	32B6	1	5.01	33.76	21.74	18.41	2
BK39N	12	32 E5	1	0.48	4.76	2.12		0
BK39N	12	32B3	1	4.35	34.21	14.78	14.84	2
BK39N	13	34C10	1	0.97	15.28	5.23	15.28	1
BK39N	13	34H10	1	4.28	51.21	18.65		
BK39N	13	34I6	1	1.91	21.76	15.82		
BK39N	13	34F4	1	5.85	140.71	50.36	84.74	3
BK39N	13	34G4	1	0.65	8.41	8.95	4.17	2
BK39N	13	34F3	1	4.09	67.83	16.62	67.83	1
BK39N	14	36F10	1	1.66	32.24	13.75	32.24	2
BK39N	14	36F8	1	5.43	101.59	45.85	63.94	5
BK39N	14	36F7	1	4.42	65.64	26.93	19.47	1
BK39N	14	36 E7	1	2.27	6.79	4.54		
BK39N	14	36D7	1	1.77	5.46	3.19		
BK39N	14	36A6	1	2.62	18.98	14.42	6.85	3
BK39N	14	36F5	1	2.52	8.84	4.46	6.01	1
BK39N	14	36F4	1	3.43	43.44	24.19	43.44	2
BK39N	14	36A3	1	2.52	19.23	5.20	19.23	1
BK39N	15	38C10	1	6.34	80.11	24.99	80.11	1
BK39N	15	38I9	1	3.02	88.47	16.12	88.47	1
BK39N	15	38D9	1	2.66	51.17	16.37		
BK39N	15	38B8	1	4.80	43.25	13.77	14.72	1
BK39N	15	38B7	1	3.81	19.12	9.85	19.12	1
BK39N	15	38A3	1	3.36	58.82	21.99	38.88	4
BK39N	16	310D10	1	4.21	56.96	22.65	56.96	3
BK39N	16	310B8	1	7.48	56.02	22.81	56.02	3
BK39N	16	310D7	1	2.27	26.03	15.99	19.28	2
BK39N	16	310 E6	1	6.40	50.33	14.65	50.33	1
BK39N	16	310 F4	1	3.59	69.49	7.11		
BK39N	17	312B8	1	2.97	29.17	18.30		
BK39N	17	312G7	1	2.49	29.15	12.49	20.40	3
BK39N	17	312C4	1	4.93	20.16	15.24		
BK39N	18	314H10	1	1.36	21.61	7.61	21.61	1
BK39N	18	314 E8	1	3.65	29.32	7.41	29.32	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK39N	18	314I8	1	4.68	41.02	24.32	18.82	2
BK39N	18	314C71	1	4.57	48.12	20.84		
BK39N	18	314C72	1	0.85	14.96	4.26		
BK39N	18	314A7	1	2.44	15.63	5.60	14.12	1
BK39N	18	314 E4	1	3.51	25.80	10.00	25.80	1
BK39N	18	314B1	1	2.64	76.45	30.10	76.45	1
BK39N	19	316G9	1	4.88	23.37	11.64	10.08	2
BK39N	19	316D9	1	0.51	3.47	1.31		0
BK39N	19	316C9	1	4.22	43.10	26.45	32.68	1
BK39N	19	316I7	1	3.37	19.31	11.58		
BK39N	19	316G7	1	0.79	15.80	3.05		
BK39N	19	316A5	1	3.21	14.66	10.85		
BK39N	19	316C11	1	0.62	7.58	2.54		0
BK39N	19	316C12	1	1.60	24.54	11.54	23.50	2
BK39N	20	318J9	1	2.39	71.98	4.59		
BK39N	20	318J8	1	2.21	27.79	6.51		
BK39N	20	318H7	1	2.73	48.14	12.29	42.31	2
BK39N	20	318G7	1	2.03	41.59	12.95	41.59	1
BK39N	20	318B6	1	4.06	47.97	13.47		
BK39N	20	318H6	1	7.11	94.52	18.20	94.52	1
BK39N	20	318C5	1	3.19	15.41	7.46		
BK39N	20	318B5	1	2.19	27.46	10.22	20.44	2
BK39N	20	318A5	1	3.40	48.54	14.63		
BK39N	20	318G4	1	3.02	12.91	7.72	12.91	2
BK39N	20	318H4	1	3.97	24.39	11.81		
BK39-N	20	318G3	1	0.80	9.28	8.66	9.28	1
BK39-N	20	318H1	1	2.47	30.14	14.05	30.14	2
BK39-N	21	70C10	1	1.95	46.88	9.02	46.88	1
BK39-N	21	70G8	1	2.27	12.93	6.02		
BK39-N	23	74B3	1	4.70	30.73	12.38	15.77	2
BK39-N	24	76C10	1	3.78	31.81	15.20	14.71	1
BK39-N	24	76B6	1	2.61	37.61	27.12	37.61	2
BK39-N	24	76B5	1	2.70	18.40	12.54	11.05	1
BK39-N	25	78I91	1	3.22	56.16	22.60	56.16	1
BK39-N	25	78I92	1	3.11	58.48	22.89	29.45	2
BK39-N	25	78J5	1	3.02	19.39	11.30		
BK39-N	25	78G2	1	9.57	76.90	32.37		
BK39-N	25	78I1	1	2.83	23.15	7.21	12.67	2
BK39-N	25	78 E1	1	1.31	25.80	11.76		
BK39-N	26	710C10	1	2.11	22.70	13.82	22.70	1
BK39-N	26	710 E8	1	3.33	49.59	25.45		
BK39-N	26	710F4	1	1.81	85.93	8.44	22.14	1
BK39-N	26	710C2	1	1.16	15.08	7.21		

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BK39-N	28	714C10	1	2.73	27.24	12.41	11.62	1
BK39-N	28	714I6	1	1.42	20.43	10.34	9.90	2
BK39-N	29	716I81	1	2.54	28.81	14.14	28.81	1
BK39-N	29	716I82	1	3.54	60.54	22.26	17.37	2
BK39-N	29	716I83	1	1.93	17.45	13.17		
BK39-N	29	716J5	1	1.75	66.64	7.28		
BK39-N	29	716G5	1	4.26	37.12	8.50		
BK39-N	30	718A9	1	1.57	6.06	5.32		
BK39-N	30	718A8	1	1.82	14.91	10.44		
BK39-N	30	718H7	1	1.92	25.36	15.52	25.36	1
BK39-N	30	718C6	1	1.71	49.72	19.32	38.10	3
BK39-N	30	718H2	1	3.73	17.08	15.20		
BKD-D	1	10A10	1	0.87	2.41	0.96		0
BKD-D	1	10C10	1	0.84	23.15	10.73	9.03	2
BKD-D	1	10D101	1	0.82	10.18	4.97	6.34	2
BKD-D	1	10D1 2	1	1.45	10.53	4.48	10.53	1
BKD-D	1	10 E10	1	2.60	21.51	7.98	21.51	1
BKD-D	1	10G10	1	3.19	26.29	11.15	9.80	1
BKD-D	1	10H10	1	4.31	33.97	18.14	17.41	2
BKD-D	1	10I10	1	1.38	10.82	5.60	7.24	2
BKD-D	1	10J9	1	3.99	78.70	33.44	50.44	2
BKD-D	1	10H9	1	7.98	41.63	17.36	31.99	2
BKD-D	1	10G91	1	3.10	18.88	9.89	18.88	1
BKD-D	1	10G92	1	0.91	5.10	2.66	5.10	1
BKD-D	1	10 E9	1	2.14	44.36	11.90	29.36	2
BKD-D	1	10D9	1	1.03	21.29	7.34	21.29	1
BKD-D	1	10C9	1	6.30	32.48	23.42	20.02	3
BKD-D	1	10A9	1	1.32	19.22	7.71	19.22	1
BKD-D	1	10A8	1	1.57	47.58	17.73	47.58	3
BKD-D	1	10B8	2		89.24	81.50		
BKD-D	1	10C8	1	0.89	6.22	4.08		0
BKD-D	1	10D8	1	5.99	56.37	36.89	56.37	4
BKD-D	1	10F81	1	3.07	15.66	5.08	15.66	1
BKD-D	1	10F82	1	4.25	56.26	20.01	37.10	2
BKD-D	1	10G81	1	1.84	46.17	12.65	26.28	4
BKD-D	2	12A4	1	4.01	96.92	28.68	55.08	3
BKD-D	2	12B6	1	6.09	109.02	27.87	61.65	5
BKD-D	2	12F7	1	6.13	102.69	32.91	102.69	2
BKD-D	2	12H7	1	5.63	54.82	46.99	33.82	3
BKD-D	2	12G8	1	7.95	48.17	23.67	28.81	2
BKD-D	2	12J9	1	0.51	4.79	2.84		0
BKD-D	2	12J91	1	3.30	32.64	20.32	32.64	1
BKD-D	2	12B71	1	4.44	26.24	15.26	18.20	3
BKD-D	2	12B72	1	1.56	12.94	8.00	10.43	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BKD-D	2	12A6	1	4.19	50.50	24.13	17.30	2
BKD-D	2	12B61	1	0.92	6.59	2.21		0
BKD-D	2	12B62	1	1.11	12.25	8.70	9.95	2
BKD-D	2	12E61	1	3.60	27.21	14.24	27.21	1
BKD-D	3	13E62	1	0.54	4.02	1.80		0
BKD-D	3	13F6	1	1.05	13.47	1.53		0
BKD-D	3	13G6	1	6.49	98.20	63.85	98.20	4
BKD-D	3	13I6	1	1.24	9.28	5.33		
BKD-D	3	13J6	1	4.35	11.74	8.53		
BKD-D	3	13H5	1	0.26	2.37	1.67		
BKD-D	3	13G6	1	4.58	39.12	17.72	39.12	1
BKD-D	3	13F5	1	6.35	43.25	23.87	32.67	2
BKD-D	3	13E5	1	0.46	3.31	2.01		0
BKD-D	3	13D51	1	5.18	27.36	22.26		
BKD-D	3	13D52	1	3.89	60.21	27.47	22.39	3
BKD-D	3	13C5	1	1.48	14.11	8.40	14.11	1
BKD-D	3	13D4	1	6.92	30.07	16.28	23.89	3
BKD-D	3	13A4	1	0.70	10.35	3.95		0
BKD-D	3	13C41	1	0.69	6.97	1.03		0
BKD-D	4	16C42	1	2.01	14.49	4.51	14.49	1
BKD-D	4	16D41	1	4.45	39.38	18.73	21.54	3
BKD-D	4	16D42	1	0.52	2.52	1.46		0
BKD-D	4	16 E4	1	4.33	54.61	32.89	54.61	3
BKD-D	4	16G4	1	4.64	30.05	18.45	30.05	1
BKD-D	4	16H4	1	2.41	15.94	10.71	7.25	2
BKD-D	4	16J4	2	9.18	60.82	76.40	53.37	5
BKD-D	4	16J3	1	0.50	5.32	2.64		0
BKD-D	4	16I3	2	4.17	37.79	24.83	37.79	2
BKD-D	4	16H3	1	2.47	26.83	12.25	26.83	1
BKD-D	4	16G31	1	1.17	8.82	4.81	8.82	1
BKD-D	4	16G32	1	0.67	3.89	3.04		
BKD-D	4	16G33	1	4.47	17.77	10.35	17.77	2
BKD-D	4	16F31	1	1.81	25.79	11.47	25.79	1
BKD-D	4	16F32	1	4.62	39.39	28.78	38.72	3
BKD-D	4	16F33	1	2.27	38.28	22.31	25.25	2
BKD-D	4	16E31	1	4.82	35.89	23.18	30.53	5
BKD-D	4	16E32	1	4.13	21.68	12.36	15.21	2
BKD-D	5	20A31	1	5.73	44.77	37.03	43.34	2
BKD-D	5	20A32	1	5.65	40.92	24.35	40.92	2
BKD-D	5	20A2	1	2.50	60.90	21.40	34.01	3
BKD-D	5	20B2	1	0.47	1.45	0.76		0
BKD-D	5	20D2	1	5.12	25.02	11.23	14.41	1
BKD-D	5	20E2	1	3.04	23.19	9.74	15.44	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BKD-D	5	20G2	1	6.67	56.22	31.68	40.72	4
BKD-D	5	20I2	1	2.31	29.84	8.96	21.57	2
BKD-D	5	20I1	1	9.98	110.66	50.47	110.66	2
BKD-D	5	20H1	1	8.58	95.47	70.27	73.61	4
BKD-D	5	20F11	2	13.97	124.81	56.50	64.45	4
BKD-D	5	20F12	1	0.61	1.27	0.97		0
BKD-D	5	20E1	1	5.89	91.33	49.69	91.33	3
BKD-D	6	23B1	1	5.36	44.07	21.41		
BKD-D	6	23A1	1	9.19	41.06	19.31		
BKD-D	6	23A10	1	3.15	35.73	25.07	20.45	3
BKD-D	6	23C10	1	1.51	15.95	10.30	9.55	2
BKD-D	6	23D10	1	1.20	15.15	7.14	11.18	2
BKD-D	6	23H10	1	1.17	8.94	5.89	6.53	2
BKD-D	6	23I10	1	1.11	11.62	5.72	11.62	1
BKD-D	6	23J10	2	0.95	34.80	19.55	17.71	3
BKD-D	6	23J91	1	0.72	6.12	3.02		0
BKD-D	6	23J92	1	1.66	13.25	6.89		
BKD-D	6	23G9	1	1.22	24.76	10.93	20.05	4
BKD-D	6	23A9	2	3.81	41.48	29.74	24.74	1
BKD-D	6	23G8	1	2.90	15.91	7.59	12.13	2
BKD-D	7	26H81	1	0.73	16.17	5.81	7.81	2
BKD-D	7	26H82	1	3.39	23.32	19.31	14.52	2
BKD-D	7	26I8	1	2.35	25.91	14.93	13.80	4
BKD-D	7	26D6	1	2.71	26.24	12.38	26.24	2
BKD-D	7	26F5	1	2.24	16.94	13.41	13.83	2
BKD-D	7	26D5	1	6.03	40.25	27.17	23.84	3
BKD-D	7	26B5	1	3.34	36.79	19.51	15.64	3
BKD-D	7	26A41	1	6.32	20.90	10.84	18.93	3
BKD-D	7	26A42	1	3.67	17.00	13.00	17.00	2
BKD-D	7	26D41	1	0.93	17.23	4.90	9.41	2
BKD-D	7	26D42	1	1.44	14.02	5.14	14.02	1
BKD-D	7	26D43	1	1.43	9.87	4.35	9.87	1
BKD-D	7	26E4	2	7.78	72.64	46.72	72.64	4
BKD-D	7	26F41	1	0.79	4.07	2.38	4.07	1
BKD-D	7	26F42	1	0.37	4.74	1.11		0
BKD-D	7	26H4	2	5.81	73.74	27.62	43.74	3
BKD-D	7	26I4	1	1.18	5.36	3.01		
BKD-D	7	26A2	2	6.65	135.42	63.28	118.08	8
BKD-D	8	30B21	1	2.30	20.80	9.37	12.99	3
BKD-D	8	30B22	1	1.51	14.25	8.47		
BKD-D	8	30B23	1	1.24	9.76	7.87	6.82	1
BKD-D	8	30C21	1		14.24	5.99		
BKD-D	8	30C22	1	1.09	14.99	5.16	14.99	1
BKD-D	8	30C23	1	1.59	16.13	7.91	16.13	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BKD-D	8	30G11	1	4.40	22.51	20.48	13.93	4
BKD-D	8	30G12	1	1.25	12.26	7.48	11.56	3
BKD-D	8	30B1	2	1.17	42.78	28.71		
BKD-D	8	30F10	1	1.31	32.56	13.88	17.35	2
BKD-D	8	30G101	1	1.50	18.19	10.31	18.19	1
BKD-D	8	30G102	2	1.89	19.33	8.79	19.33	2
BKD-D	9	33A9	1	5.95	65.05	15.94	44.02	3
BKD-D	9	33I10	1	1.55	11.95	6.37	9.19	2
BKD-D	9	33J10	1	4.53	19.40	9.63	11.73	2
BKD-D	9	33G9	1	1.41	11.69	6.68	11.69	2
BKD-D	9	33 E81	1	3.45	31.84	17.57	21.17	2
BKD-D	9	33 E82	1	2.60	28.88	23.30	17.18	2
BKD-D	9	33J8	1	0.58	3.30	2.52		0
BKD-D	9	33G7	1	1.48	23.10	12.68	20.36	2
BKD-D	9	33F7	1	0.81	7.32	4.53	7.32	2
BKD-D	9	33D7	1	0.69	4.50	2.61		0
BKD-D	9	33G61	1	1.44	15.11	7.87	10.93	2
BKD-D	9	33G62	1	3.09	32.83	16.33	16.90	4
BKD-D	9	33I5	1	5.93	50.08	27.91		
BKD-D	10	36F5	1	9.36	66.15	42.58	55.60	3
BKD-D	10	36C5	1	8.62	49.50	37.70	46.38	3
BKD-D	10	36A5	1	6.67	35.47	19.71	19.65	6
BKD-D	10	36C4	1	0.76	6.05	4.44	5.11	2
BKD-D	10	36H3	1	6.57	97.56	78.16		
BKD-D	10	36A2	2	4.64	46.16	30.08	32.58	2
BKD-D	10	36J1	2	7.15	40.71	22.09	40.71	2
BKD-D	10	36 E1	1	4.62	25.40	14.64	15.91	2
BKD-D	10	36A10	1	4.66	37.26	29.69	20.52	3
BKD-D	10	36B101	1	4.55	50.44	27.84	18.53	3
BKD-D	11	40A3	1	4.53	33.38	17.83	33.38	2
BKD-D	11	40B3	1	3.92	49.99	25.50	21.93	3
BKD-D	11	40C7	1	2.50	14.64	12.26	9.78	3
BKD-D	11	40D8	1	1.86	16.19	11.36	16.19	2
BKD-D	11	40C104	1	1.88	16.11	10.85	10.60	2
BKD-D	11	40D10	1	2.88	10.59	5.59	4.71	3
BKD-D	11	40F10	1	0.62	5.02	1.95		0
BKD-D	11	40I101	1	1.42	9.70	6.09	9.70	2
BKD-D	11	40I102	1	1.88	6.97	4.27	6.97	2
BKD-D	11	40I103	1	2.25	17.51	12.18	17.51	3
BKD-D	11	40I104	1	0.49	5.00	2.91		0
BKD-D	12	43J10	1	10.45	70.33	30.75		
BKD-D	12	43J9 1	1	4.38	22.70	13.07		
BKD-D	12	43J9 2	1	0.64	11.08	4.63	6.38	2
BKD-D	12	43I9	1	2.17	18.65	11.10	18.65	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BKD-D	12	43G9	2	4.12	101.40	40.79	45.06	5
BKD-D	12	43E9	1	2.99	29.24	9.17	14.01	3
BKD-D	13	43A8	1	1.78	17.20	11.47	17.20	1
BKD-D	13	43B92	1	3.29	30.17	17.34	20.70	3
BKD-D	13	43H8	2	3.36	21.71	19.36	38.08	2
BKD-D	13	43C7	1	2.45	19.58	11.30	15.64	2
BKD-D	13	46J8	1	2.62	17.96	10.58		
BKD-D	13	43J71	1	2.51	22.50	16.47	22.50	1
BKD-D	13	43J72	1	3.13	16.34	12.00		
BKD-D	13	43E7	1	4.14	37.11	18.36	32.22	2
BKD-D	13	43D7	1	1.43	15.70	6.01	15.70	2
BKD-D	13	43I5	1	2.49	11.60	4.28	7.99	2
BKD-D	13	43C5	1	4.85	23.50	12.36	14.18	3
BKD-D	13	43C4	1	5.40	109.79	35.81	40.03	3
BKD-D	14	50C3	1	9.48	88.18	40.65		
BKD-D	14	50J3	1	3.31	46.00	32.57	46.00	3
BKD-D	14	50I3	1	1.59	12.71	4.71	8.67	2
BKD-D	14	50H3	1	0.48	4.58	2.23		0
BKD-D	14	50B2	1	4.27	57.95	36.46	25.67	2
BKD-D	14	50C2	1	2.08	25.22	15.22	17.76	2
BKD-D	14	50A10	1	7.21	21.32	14.32	21.32	2
BKD-D	14	50F81	1	1.60	11.80	5.06	7.11	1
BKD-D	14	50F82	1	1.48	34.76	14.47	21.50	2
BKD-D	15	53D4	1	3.32	37.42	21.08	15.59	2
BKD-D	15	53F6	1	3.78	63.97	29.84		
BKD-D	15	53G5	1	3.77	22.35	13.48		
BKD-D	15	53F5	1	5.43	26.64	12.67	26.64	2
BKD-D	15	53E51	1	1.40	13.26	6.65	8.73	2
BKD-D	15	53E52	1	2.94	32.52	20.62	32.52	3
BKD-D	15	53D5	1	5.58	53.77	31.42	44.69	2
BKD-D	15	53A3	1	2.62	63.90	20.65	32.46	1
BKD-D	15	53B3	1	2.15	13.61	9.88	9.26	2
BKD-D	15	53E3	1	3.29	21.13	9.40	21.13	1
BKD-D	15	53G3	1	0.48	3.70	1.65		0
BKD-D	16	56F2	1	0.79	11.76	5.49	5.50	2
BKD-D	16	56D2	1	1.98	23.98	13.59	23.98	1
BKD-D	16	56C2	1	4.24	16.22	7.21	7.21	2
BKD-D	16	56B2	1	1.01	9.43	4.00	9.43	1
BKD-D	16	56C1	1	0.62	5.61	2.42		0
BKD-D	16	56D1	1	2.15	18.41	9.17		
BKD-D	16	56J1	1	3.89	55.25	20.36	46.87	3
CNA-N	1	10C7	1	2.22	22.43	15.42	22.43	1
CNA-N	1	10B7	1	0.99	22.35	18.37	22.35	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	1	10I3	1	1.42	18.53	6.63	18.53	1
CNA-N	2	11F9	1	1.25	13.61	8.37	13.61	1
CNA-N	2	11A8	1		18.72	14.22		0
CNA-N	2	11F3	1	0.53	7.65	2.21	7.65	1
CNA-N	3	11A2	1	1.72	35.21	10.18	35.21	2
CNA-N	3	11C2	1		25.84	8.90		0
CNA-N	4	12D1	1	6.76	54.80	25.26	27.85	2
CNA-N	4	12B4	1	0.82	10.23	3.86		0
CNA-N	4	13D10	1	1.65	20.28	15.16	20.28	2
CNA-N	4	13I10	1	11.31	137.71	98.46	84.31	4
CNA-N	4	13B9	3	2.76	26.44	18.96	10.82	3
CNA-N	4	13C3	1		31.21	4.68	18.07	2
CNA-N	5	14D5	2	3.58	38.64	23.90	16.08	3
CNA-N	5	14E3	1	0.49	4.57	5.91		0
CNA-N	5	14B3	1	1.69	1.64	14.50	8.30	2
CNA-N	5	14A3	1	2.03	47.57	29.73	41.71	4
CNA-N	5	14A2	1	4.53	43.31	39.28	19.66	3
CNA-N	6	15E10	1	1.54	31.41	10.92	17.12	2
CNA-N	6	15D9	1	2.59	34.74	33.56	34.74	1
CNA-N	6	15H8	2	6.04	101.71	32.18	77.19	2
CNA-N	6	15J7	2	5.36	113.28	27.65	68.25	2
CNA-N	6	15B7	1	1.14	15.84	7.56	15.84	1
CNA-N	6	15F3	1	3.02	31.11	17.67	31.11	1
CNA-N	6	15D3	1	5.28	18.05	12.99	18.05	3
CNA-N	7	16J9	1	5.02	49.23	15.30	31.51	3
CNA-N	7	16I9	1	2.85	103.30	45.98		
CNA-N	7	16C8	1	6.60	84.34	44.49	44.57	2
CNA-N	7	16C7	3	4.50	30.12	22.25	30.00	2
CNA-N	7	16F7	3	4.80	51.26	33.31	36.97	2
CNA-N	7	16I7	3	1.79	27.20	16.50	20.80	2
CNA-N	7	16J7	1	1.37	23.30	15.35	7.49	2
CNA-N	7	16F6	1	1.86	15.97	8.64	9.75	3
CNA-N	7	16I3	1	2.86	27.20	24.90	46.09	2
CNA-N	7	16H2	1	4.05	15.97	43.49	40.43	2
CNA-N	8	17I10	1	1.83	20.43	13.00	14.60	2
CNA-N	8	17I9	1	1.46	17.55	9.83	17.55	1
CNA-N	8	17C9	2	3.40	29.40	15.83	15.21	2
CNA-N	8	17A8	1	1.61	11.96	14.09	9.36	3
CNA-N	8	17J7	2	2.84	31.65	19.61	20.49	2
CNA-N	8	17H7	1	2.69	44.75	23.86	38.17	2
CNA-N	8	17H6	2	9.31	34.16	22.25	30.15	5
CNA-N	8	17H4	3	3.85	49.88	20.97	29.17	2
CNA-N	8	17H3	1	0.88	12.68	8.31	12.68	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	8	17E2	1	1.57	39.45	24.67	35.10	2
CNA-N	9	18J10	2	5.15	67.22	41.83	41.25	4
CNA-N	9	18H7	1	4.94	75.23	41.60	43.48	3
CNA-N	9	18F7	3	8.94	82.52	51.32	82.52	5
CNA-N	9	18 E6	1	1.13	14.17	9.81	11.18	2
CNA-N	9	18I5	1	5.84	54.89	47.99	33.32	2
CNA-N	9	18J3	3	6.67	92.57	54.53	52.32	5
CNA-N	9	18H1	1	2.27	37.96	20.86	23.90	4
CNA-N	10	19J9	1	1.30	14.92	12.26	6.78	3
CNA-N	10	19I9	1	2.38	16.90	5.87	11.97	1
CNA-N	10	19G8	3	5.20	83.06	46.42	46.36	7
CNA-N	10	19A2	3	3.83	42.25	27.24	36.01	2
CNA-N	10	19E6	1	1.01	16.84	4.23	10.95	1
CNA-N	10	19C5	1	2.82	35.84	20.48	23.76	2
CNA-N	10	19D3	1	2.72	55.40	38.70	28.10	3
CNA-N	13	I12B8	1	8.64	104.53	54.18	99.56	3
CNA-N	15	114D1	2		90.14	40.44	42.16	7
CNA-N	18	117H81	1	1.00	9.13	2.52		
CNA-N	18	117H82	1	0.58	7.02	4.20		0
CNA-N	18	117J7	1	2.75	41.21	20.60	34.77	2
CNA-N	19	118I6	1	4.81	62.44	31.23	54.50	2
CNA-N	19	118H5	1	0.56	11.09	6.34		0
CNA-N	19	118I5	1	0.78	10.80	5.07	6.12	2
CNA-N	19	118 E7	1	1.15	18.87	6.70	6.70	2
CNA-N	19	118B3	1	1.38	2.63	1.89		0
CNA-N	20	119H10	1	0.93	23.76	8.66	18.22	2
CNA-N	20	119G5	1	1.34	36.41	21.96	26.19	2
CNA-N	21	20E10	1	3.23	41.69	24.34	23.90	2
CNA-N	21	20F10	2	3.54	30.28	17.15	26.20	3
CNA-N	21	20J9	1	3.54	90.89	21.15	49.27	3
CNA-N	21	20H6	1		75.88	44.09	61.24	8
CNA-N	21	20A5	1	3.89	36.15	21.94	34.00	2
CNA-N	21	20B2	1		58.76	32.85		
CNA-N	21	20G7	1	1.28	15.24	10.95	12.47	2
CNA-N	21	20A2	2	1.41	17.62	13.39	11.04	2
CNA-N	22	22D9	1	0.81	20.90	6.72	10.87	3
CNA-N	22	22D8	2	3.85	49.82	28.23	26.03	5
CNA-N	22	22G7	3	4.97	25.90	16.30	20.63	4
CNA-N	22	22J6	1	2.09	19.49	13.99	13.52	2
CNA-N	22	22A5	2	3.65	84.59	34.92	21.80	3
CNA-N	22	22F5	2	2.81	107.59	44.98	70.88	3
CNA-N	22	22B2	1	5.89	50.07	34.17	32.41	3
CNA-N	22	22D1	2	6.78	129.17	75.67	72.17	4

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	23	24A101	2	3.62	17.64	10.50	17.64	2
CNA-N	23	24A102	2		35.09	17.41	24.15	2
CNA-N	23	24B10	1	0.68	12.16	8.15	5.93	3
CNA-N	23	24D10	1	3.14	46.19	26.03	23.77	5
CNA-N	23	24H10	2	5.68	87.19	66.77	56.31	3
CNA-N	23	24F9	3	5.58	48.98	27.70	37.65	5
CNA-N	24	26A10	2	3.28	68.00	35.21	68.00	1
CNA-N	24	26D9	2	3.30	64.59	32.14	42.55	2
CNA-N	24	26J9	3	2.08	27.90	15.13	17.02	2
CNA-N	24	26A6	3		26.76	21.34		
CNA-N	25	28D8	2	4.91	79.41	40.55	42.67	3
CNA-N	27	212A8	1	2.38	30.06	18.29	28.74	2
CNA-N	27	212H9	3	1.67	23.01	21.92	21.20	2
CNA-N	27	212J6	2	5.23	109.88	53.62	81.46	2
CNA-N	27	212D1	1	1.92	19.04	13.43	11.72	2
CNA-N	27	212B1	2	3.72	36.10	29.15	36.10	1
CNA-N	28	214A91	1	2.19	30.78	14.45	18.68	2
CNA-N	28	214A92	1	1.27	16.23	10.88	8.89	2
CNA-N	28	214J5	2	8.17	62.23	36.47	50.94	4
CNA-N	28	214B21	3	4.45	69.63	24.45	32.18	3
CNA-N	28	214B22	3	1.62	24.36	9.41	17.18	2
CNA-N	29	216H3	1		38.16	22.33		
CNA-N	29	216J8	3	5.23	39.41	31.27	22.71	3
CNA-N	29	216J9	1	1.89	28.38	15.85	20.63	3
CNA-N	30	218D8	2	4.98	54.22	30.57	21.95	3
CNA-N	30	218I9	1	1.10	12.03	8.37	6.69	2
CNA-N	30	218J5	1	3.21	52.75	19.20	51.45	2
CNA-N	30	218F2	1	3.44	15.84	9.49	10.57	3
CNA-N	31	30I9	1	4.52	52.50	22.73	32.31	3
CNA-N	31	30G9	1	1.96	31.79	14.92	25.51	2
CNA-N	31	30D8	2	5.81	53.82	31.14	28.45	3
CNA-N	31	30F8	1	2.27	15.83	12.33	15.83	1
CNA-N	31	30G7	1	6.43	28.20	11.04	11.90	2
CNA-N	31	30G6	1	1.03	18.62	7.70	12.42	3
CNA-N	31	30H4	1	2.40	23.58	17.25	7.41	4
CNA-N	31	30J3	2	3.62	89.72	25.98	81.66	2
CNA-N	32	32B10	1	1.62	31.89	12.97	31.89	1
CNA-N	32	32B8	2	11.47	67.17	19.74	35.13	3
CNA-N	32	32D7	2	9.79	51.03	28.56	39.72	2
CNA-N	32	32I8	1	1.58	10.32	5.49	11.29	1
CNA-N	32	32I6	1	3.59	6.04	3.30		
CNA-N	32	32H5	1		11.76	5.49		
CNA-N	32	32A3	2	7.27	60.64	32.82	57.27	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	33	34G9	2	4.59	31.24	17.18	18.63	3
CNA-N	33	34C9	2		31.37	7.33		
CNA-N	33	34A8	1	3.65	29.57	25.70	20.50	5
CNA-N	33	34B7	1	3.75	71.76	23.78	53.21	2
CNA-N	33	34F6	1	1.08	15.47	4.76	8.67	1
CNA-N	33	34H5	1	11.50	34.31	30.65		
CNA-N	33	34 E3	2	3.02	57.48	34.33	48.56	2
CNA-N	34	36H7	1	3.13	20.43	9.88	12.37	3
CNA-N	34	36G3	1	4.72	44.86	26.70	36.09	3
CNA-N	34	36B2	1	7.98	87.54	34.45	42.32	4
CNA-N	35	38E7	1	4.15	146.96	50.11	80.22	3
CNA-N	35	38F8	1	2.67	18.76	8.25	8.58	2
CNA-N	35	38J7	3	3.90	141.28	70.28		
CNA-N	35	38G6	1	5.51	30.69	13.16	11.17	4
CNA-N	36	310D10	2	3.40	44.59	18.01	15.53	3
CNA-N	37	312C9	1	5.77	123.04	92.17		
CNA-N	37	312H7	2	7.48	71.71	34.93	27.72	2
CNA-N	38	314F9	1		108.51	61.85		
CNA-N	38	314 E7	1	1.86	12.21	5.70	5.78	3
CNA-N	38	314B41	1	2.04	21.38	9.54	6.56	3
CNA-N	38	314B42	1	1.44	8.52	4.56		0
CNA-N	40	318C1	1	1.95	21.54	9.37	12.37	3
CNA-N	41	50C2	1	1.22	24.51	11.12	13.86	2
CNA-N	42	52D10	1	5.39	33.00	13.52	14.84	2
CNA-N	42	52B5	2	1.83	23.89	7.56	16.07	3
CNA-N	42	52C3	1	2.00	21.19	15.59	14.55	3
CNA-N	42	52A3	1	2.22	32.43	19.18	32.43	1
CNA-N	42	52F2	1	2.62	90.64	57.87	84.53	2
CNA-N	42	52H1	1	2.29	23.42	13.48	12.94	2
CNA-N	42	52C1	1	2.31	40.36	5.26	33.57	2
CNA-N	44	52A1	1	2.40	11.57	6.22	9.74	2
CNA-N	42	52G3	1	1.27	43.34	12.69	34.72	2
CNA-N	43	54B7	1	1.54	14.50	3.85	14.50	1
CNA-N	43	54B4	1	3.92	79.31	84.96	75.65	4
CNA-N	43	54B1	1	7.14	36.66	10.10	16.87	3
CNA-N	44	56A10	1	3.50	115.35	73.43	58.35	4
CNA-N	44	56G10	1	3.30	96.66	49.10	34.97	3
CNA-N	44	56I9	1	3.98	52.04	20.91	43.83	1
CNA-N	44	56H8	1	4.25	45.50	13.70	28.64	2
CNA-N	44	56A7	3	10.38	133.63	48.90	47.77	3
CNA-N	44	56E7	2	7.76	138.75	121.99	92.04	4
CNA-N	44	56F8	1	2.13	35.72	15.51	15.70	1
CNA-N	44	56B4	2	5.27	214.00	110.56	90.84	9

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	44	56H5	2	5.18	122.00	67.22	40.65	2
CNA-N	44	56G2	2	19.30	308.00	136.79	109.23	9
CNA-N	45	58G7	1	5.92	208.01	204.00	117.93	12
CNA-N	45	58J7	1	3.05	99.39	62.28		3
CNA-N	45	58A3	1	11.63	116.75	89.89		
CNA-N	46	510J9	1	9.20	153.75	92.64		
CNA-N	46	510H6	2	20.65	216.00	214.00	127.81	6
CNA-N	46	510F1	1	5.70	106.16	52.86	54.19	3
CNA-N	46	510 E1	2		224.00	154.70		
CNA-N	47	60F4	1	4.19	106.74	46.61	42.79	2
CNA-N	48	62A10	2	2.93	56.50	46.45	44.01	1
CNA-N	48	62G10	1	4.85	27.82	18.69	14.21	3
CNA-N	48	62H8	1	1.48	12.46	6.89	12.46	1
CNA-N	48	62B4	1		256.16	89.77		5
CNA-N	49	64A9	1	1.15	15.76	3.55		0
CNA-N	49	64F7	1	3.64	255.49	153.69	98.79	5
CNA-N	49	64A5	3	3.53	61.62	17.84	61.62	1
CNA-N	50	66A1	1	2.25	58.95	32.22	20.91	2
CNA-N	50	66B1	1	6.85	80.16	40.30	67.03	1
CNA-N	51	68C9	1	4.19	76.11	31.33	51.09	2
CNA-N	51	68G9	1	4.97	23.96	16.04	10.62	1
CNA-N	51	68H8	1	3.44	88.05	37.64	50.36	4
CNA-N	51	68B7	1	3.70	108.02	70.97		
CNA-N	51	68E5	1	4.37	79.44	50.45	69.78	3
CNA-N	51	68A2	2	6.86	256.14	66.35	70.99	5
CNA-N	52	610B8	2	3.20	44.38	19.12	25.12	1
CNA-N	52	610H7	2	3.90	65.73	53.91	31.53	5
CNA-N	52	610D3	1	2.16	23.62	15.79	9.66	3
CNA-N	52	610E3	1	0.82	11.24	7.86	7.08	3
CNA-N	52	610I1	1	0.54	25.24	16.17	17.20	3
CNA-N	52	610F1	1	9.31	110.65	69.60		
CNA-N	53	612B10	1	9.96	101.09	54.34	64.43	2
CNA-N	53	612D10	1	9.06	53.17	39.46	33.81	5
CNA-N	53	612E10	3	4.05	94.64	50.49	65.82	3
CNA-N	53	612C7	1	1.48	21.66	14.44	8.05	2
CNA-N	53	612B5	1	4.09	148.38	72.93	49.78	3
CNA-N	54	614A7	1	6.99	80.98	50.56	55.56	4
CNA-N	54	614B4	1	1.01	21.00	6.61	21.00	1
CNA-N	55	616F4	1	1.26	18.03	8.82	15.11	2
CNA-N	56	618B10	1	1.12	61.62	10.63	56.06	1
CNA-N	56	618I10	2	5.39	138.86	89.68		
CNA-N	58	72B10	1	2.46	219.82	65.72	104.02	3
CNA-N	59	74C8	1	2.02	19.50	12.64	8.29	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNA-N	59	74B7	1	6.05	145.83	91.18	81.07	3
CNA-N	59	74F2	1	2.50	17.06	13.76	12.67	2
CNA-N	60	76A9	1	1.07	43.07	20.13	24.57	2
CNA-N	61	78C10	1	2.51	30.66	19.63	30.66	1
CNA-N	61	78F10	1	1.00	12.87	9.58	8.02	1
CNA-N	61	78G9	3	2.72	41.77	32.97	38.21	2
CNA-N	61	78D8	1	3.77	50.66	28.81	43.08	3
CNA-N	61	78C5	1	3.34	21.26	10.56	15.09	2
CNA-N	62	710D5	1	5.07	44.30	19.73	21.56	2
CNA-N	63	712G8	1	6.99	60.66	37.16	53.28	2
CNA-N	64	714I10	1	10.71	117.79	75.37	63.41	3
CNA-N	64	714I8	2	3.48	27.66	17.26	13.90	4
CNA-N	64	714D5	1	2.78	65.80	18.66	59.07	3
CNA-N	64	714D4	1	2.15	8.55	7.16	6.26	0
CNA-N	64	714A5	1	7.69	60.01	40.87	46.49	2
CNA-N	64	714D2	3	2.63	73.55	38.21	55.87	3
CNA-N	64	714C2	1	1.34	11.92	8.09	6.11	3
CNA-N	64	714B1	1	2.33	27.19	15.00	23.93	2
CNA-N	65	716D10	2	2.99	26.28	16.49	17.76	3
CNA-N	65	716F1	1		34.45	10.57		
CNA-N	66	718I6	2	7.14	40.22	35.19	44.46	2
CNA-N	66	718B4	1	1.46	38.63	22.21	21.40	2
CNA-N	66	718B2	2	3.30	113.98	69.10	73.20	4
CNC-N	1	10D8	1	0.13	25.76	25.12	23.45	2
CNC-N	1	10I6	1	1.29	7.24	4.53	5.83	2
CNC-N	1	10F5	1	0.86	13.60	4.42		
CNC-N	2	12C6	2	11.99	153.90	40.74	126.96	3
CNC-N	2	12E5	1	0.07	2.01	0.89		
CNC-N	2	12D4	1	0.13	0.83	0.63	0.62	2
CNC-N	2	12G2	1	1.00	0.70	0.20		
CNC-N	3	14F10	1	1.00	50.10	12.00	12.00	2
CNC-N	3	14I6	1	1.00	0.40	0.20		
CNC-N	3	14G4	1	0.28	16.00	15.00	10.00	2
CNC-N	3	14C1	1	7.00	148.00	71.00	94.00	3
CNC-N	3	14B1	1	10.00	73.00	15.00	28.00	2
CNC-N	4	16E10	1	1.00	8.50	6.30		0
CNC-N	4	16G10	1	1.00	15.60	8.00	7.30	2
CNC-N	4	16J10	1	1.00	6.20	2.10		0
CNC-N	4	16J9	1	1.00	2.00	1.00		0
CNC-N	4	16C8	1	1.00	9.00	5.00		0
CNC-N	4	16J5	1	1.00	9.60	4.20		0
CNC-N	4	16H5	1	2.00	18.70	10.40		0
CNC-N	4	16G4	1	1.00	10.40	4.15		0
CNC-N	4	16J3	1	6.20	39.55	23.90	23.95	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNC-N	4	16D3	1	1.00	9.00	4.00		0
CNC-N	4	16I2	1	2.00	30.00	7.30		
CNC-N	5	18B10-1	1	0.61	14.02	1.58		0
CNC-N	5	18B10-2	1	0.81	12.55	4.30	2.13	2
CNC-N	5	18E10	3	9.17	182.04	51.85	76.69	3
CNC-N	5	18J10	1	1.22	102.83	97.78	101.84	2
CNC-N	5	18D8	1	0.94	10.04	6.80	2.90	3
CNC-N	5	18E8	1	16.50	114.80	102.00	57.10	2
CNC-N	5	18I8-1	1	1.00	5.00	3.00		
CNC-N	5	18I8-2	1	1.10	8.20	4.10		
CNC-N	5	18G5	1	1.00	9.20	2.10		0
CNC-N	5	18E4	1	1.00	9.00	7.00		0
CNC-N	5	18F4	1	1.10	4.80	2.50		0
CNC-N	5	18E1	1	1.80	38.50	14.80	8.80	2
CNC-N	6	20D10	1	7.36	40.14	14.03	21.85	2
CNC-N	6	20C8	1	0.90	7.20	3.67		0
CNC-N	6	20J7	3	8.74	57.92	27.91	40.13	2
CNC-N	6	20D7	1	1.08	15.43	11.47	7.88	2
CNC-N	6	20D6	1	0.77	6.82	2.07		0
CNC-N	6	20A5	1	10.64	43.77	26.58	11.03	2
CNC-N	6	20H4	1	0.60	3.13	1.58		0
CNC-N	6	20I3	1	0.71	14.88	3.09		0
CNC-N	6	20E3	1		34.18	18.76	13.76	3
CNC-N	6	20C3	1	0.83	7.48	5.36	4.12	2
CNC-N	6	20F2	1	2.36	12.81	10.07	7.76	2
CNC-N	6	20H1	2	3.31	34.12	22.87	28.84	3
CNC-N	7	22A10	1	2.72	33.40	15.65	29.04	1
CNC-N	7	22E8	1	2.57	9.77	3.58	9.58	1
CNC-N	7	22J7	1	13.80	52.09	37.24	34.13	3
CNC-N	7	22A6	1	6.05	53.12	24.07	25.37	4
CNC-N	7	22B5	1	1.92	8.42	5.42	7.61	1
CNC-N	7	22F2	1	1.10	10.68	3.48	9.41	1
CNC-N	7	22D1	1	3.99	78.69	31.08	41.71	3
CNC-N	8	24A5	2	13.11	134.11	85.50	60.86	2
CNC-N	8	24E3	3	5.07	58.58	25.07	35.99	3
CNC-N	8	24F3	1	0.84	20.60	7.79		
CNC-N	8	24I3	1	1.66	33.39	12.53	24.57	2
CNC-N	8	24G1	1	1.02	15.98	8.42		
CNC-N	8	24F1	1	1.53	14.20	8.88	14.45	2
CNC-N	9	26I6	1	2.91	88.82	49.97	73.07	2
CNC-N	9	26G6	3	8.32	215.00	58.86	89.84	4
CNC-N	10	28J2	1	0.96	22.13	15.27	11.76	2
CNC-N	11	28F9	1	1.48	14.74	9.41	9.85	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNC-N	11	30J8	2		64.66	31.26		
CNC-N	12	32D5	3	5.23	68.20	39.61	38.81	5
CNC-N	12	32D4	1	1.74	15.50	13.24	7.19	3
CNC-N	12	32B4	1	2.21	9.48	7.39	9.27	3
CNC-N	14	36B3	1	7.32	62.07	39.45	37.99	4
CNC-N	15	38I8	1	8.45	84.74	42.77	35.93	6
CNC-N	16	40A10	1	2.06	19.59	11.21	7.75	3
CNC-N	16	40E9	1	1.45	9.70	7.92	10.33	1
CNC-N	16	40H6	2	8.64	87.76	60.69	78.16	2
CNC-N	18	44C10	1	13.42	98.22	61.56	79.80	2
CNC-N	18	44G9	1	0.77	0.76	1.57		0
CNC-N	18	44C8	1	0.61	4.79	1.93		0
CNC-N	18	44H8	1	5.16	62.57	36.04	52.08	2
CNC-N	19	46I101	1	2.05	27.56	8.65	20.68	1
CNC-N	19	46I102	1		37.69	17.02		
CNC-N	19	46I9	1	1.32	17.11	7.85	9.00	1
CNC-N	19	46A8	1	1.56	27.95	12.26	25.79	1
CNC-N	22	52A10	3	16.56	287.21	134.43		
CNC-N	22	52I10	2	13.46	79.93	52.31	52.04	5
CNC-N	22	52G9	2	17.19	183.84	89.83		
CNC-N	22	52D9	1		44.52	28.34		
CNC-N	23	54B3	1	2.13	23.72	12.36	16.36	2
CNC-N	24	56B10	1	1.15	28.89	12.06	18.88	2
CNC-N	24	56C10	1	4.17	38.25	24.05	21.83	4
CNC-N	24	56D10	2	5.50	60.48	47.97	30.14	2
CNC-N	24	56 E10	1	2.10	29.13	19.52	21.80	2
CNC-N	24	56F10	1	1.85	22.36	15.78	20.48	2
CNC-N	24	56I101	1	2.59	12.89	7.93	5.91	3
CNC-N	24	56I102	1	1.17	10.44	2.49		0
CNC-N	24	56H9	1	2.55	42.09	21.13	25.78	3
CNC-N	24	56F9	1	1.52	8.88	5.16	4.91	2
CNC-N	24	56D8	1	0.70	18.99	6.88		0
CNC-N	24	56C1	1	1.03	23.66	3.79	7.87	2
CNC-N	24	56I3	2	11.68	142.03	57.32		
CNC-N	24	56G2	1	1.52	10.86	5.62		0
CNC-N	24	64G6	3	15.90	395.04	154.22	230.81	5
CNC-N	29	66H2	1	2.29	19.68	14.66	12.34	2
CNC-N	30	68D9	1	5.19	96.78	45.21	49.97	3
CNC-N	30	68F9	1	1.21	14.19	7.64	10.76	2
CNC-N	33	74D10	1		12.52	9.31		2
CNC-N	33	74D4	1	5.82	31.69	21.07	14.45	3
CND-D	1	10E10	1	4.37	133.53	101.40	104.32	2
CND-D	1	10F10	1		102.58	46.35		
CND-D	1	10I10	1	2.95	71.50	60.30	46.24	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	1	10C9	1		62.07	23.69		3
CND-D	1	10H8	1	3.86	286.59	95.01	80.94	3
CND-D	1	10C7	1	1.86	59.46	44.17	30.56	3
CND-D	1	10A5	1	5.10	115.52	39.87	40.92	2
CND-D	1	10G4	1	1.21	24.51	20.95	15.03	3
CND-D	1	10 E3	1	1.25	32.72	21.88	19.92	2
CND-D	1	10B3	1	1.74	67.89	62.24	47.93	2
CND-D	1	10C2	3	11.90	125.32	58.93	70.01	3
CND-D	2	12I7	1	2.07	56.68	22.12	44.94	2
CND-D	2	12C5	1	2.24	38.84	15.35	19.63	2
CND-D	2	12B5	1	2.08	22.05	14.92		
CND-D	2	12F1	3	7.17	69.53	67.57	60.39	3
CND-D	6	110G2	1	4.26	47.13	13.75	25.52	2
CND-D	7	114G7	1	8.02	92.58	56.74	66.08	2
CND-D	7	114 E4	1	1.62	21.12	14.60		
CND-D	7	114C3	1		10.32	3.50		
CND-D	8	114I9	1	1.98	33.35	18.31	22.42	1
CND-D	8	114G9	1	0.98	14.45	5.99		
CND-D	9	116G10	3	8.40	98.36	72.49	67.09	2
CND-D	9	116J9	1	2.91	59.23	15.01	31.36	1
CND-D	9	116J6	1	9.43	56.25	17.43	36.88	4
CND-D	9	116I2	1		26.57	7.63		
CND-D	10	118G4	1	4.71	106.11	53.81	66.84	5
CND-D	10	118I7	1	1.37	24.77	12.22		
CND-D	10	118 E8	1	2.92	21.30	10.83		
CND-D	11	20H7	1	2.65	75.53	26.56	31.05	3
CND-D	11	20I6	1	2.51	30.99	20.69	26.98	2
CND-D	11	20A5	3	9.74	150.49	67.11	73.81	7
CND-D	11	20C4	1	4.58	37.22	13.87	23.83	2
CND-D	11	20H2	2	15.97	144.31	65.75	75.35	5
CND-D	11	20H1	1	2.69	86.91	41.92	50.69	2
CND-D	12	22A8	1	3.25	63.24	34.93	29.54	3
CND-D	15	28F6	1	2.68	25.54	18.37	22.64	2
CND-D	17	212J1	3	17.40	254.95	204.94	151.20	5
CND-D	18	214D10	1	5.65	52.67	21.43	52.67	1
CND-D	19	216F3	1	3.73	39.31	33.68	34.26	3
CND-D	20	218H5	1	7.30	104.60	39.73	89.73	3
CND-D	20	218A6	1	2.92	63.31	35.92	40.88	2
CND-D	20	218H3	1	3.02	80.18	25.47	52.43	2
CND-D	21	30I8	1	2.87	75.25	43.21	49.84	3
CND-D	21	30E2	1	1.55	20.02	13.00		
CND-D	22	32E7	1	0.87	23.40	10.30	9.58	2
CND-D	23	34E4	3	5.92	99.29	48.26	55.63	3
CND-D	23	34F5	1	2.61	111.48	43.54	79.03	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	25	38A6	1	1.56	27.53	12.70	10.75	2
CND-D	26	310B9	2	7.57	122.22	95.50	11.52	2
CND-D	26	310B7	1	2.77	25.44	20.17	16.52	2
CND-D	26	310H4	1	5.40	30.70	21.55	22.96	3
CND-D	26	310 E3	1	11.01	101.45	63.39	81.19	3
CND-D	27	312B10	1		107.57	31.46		
CND-D	27	312J8	1	11.58	143.65	75.90	70.17	3
CND-D	27	312H7	1		52.89	26.39		
CND-D	27	312H6	1	2.66	79.28	23.34	34.66	2
CND-D	27	312C3	1	19.37	374.84	200.00	251.79	7
CND-D	31	40G7	1	1.97	54.04	36.09	52.29	2
CND-D	35	48J4	1	3.88	114.80	112.51	75.37	3
CND-D	35	48I1	2	2.69	91.93	48.13	44.78	2
CND-D	35	48D5	1	7.26	57.10	38.12		
CND-D	36	410B10	1	3.81	103.06	43.82	67.36	2
CND-D	36	410F10	1	1.69	30.07	16.21	30.07	1
CND-D	36	410G8	3	11.90	132.74	101.31	92.08	2
CND-D	36	410H3	1	2.22	25.69	13.93	22.10	2
CND-D	36	410 E3	1	1.98	25.13	8.36	15.88	2
CND-D	36	410A1	2	7.07	117.33	48.82	69.43	2
CND-D	36	410J3	1	5.29	43.54	15.12	25.74	3
CND-D	37	412I7	1	2.84	69.75	34.56	38.11	3
CND-D	37	412C4	1	1.21	27.69	11.48	12.43	2
CND-D	37	412 E10	1	6.58	78.40	32.51	39.77	2
CND-D	39	416G6	1	4.22	10.67	6.28	9.69	2
CND-D	41	50F10	1	2.46	127.63	41.09	80.54	2
CND-D	41	50A7	2	3.85	62.09	20.40	46.86	3
CND-D	41	50H3	1	8.87	71.91	43.17	40.56	3
CND-D	43	54B4	3	12.40	196.38	78.19	102.08	6
CND-D	43	54J3	2	4.75	133.73	53.37	91.68	3
CND-D	43	54H2	1	3.03	67.32	25.80	31.90	3
CND-D	45	58D9	2	16.28	184.97	180.72	130.40	4
CND-D	45	58A9	1	9.41	34.22	13.02	15.07	3
CND-D	45	58F6	2	15.69	217.00	116.74		
CND-D	45	58A3	1	2.78	70.86	25.50	37.04	4
CND-D	45	58C5	1	1.83	30.75	15.17	26.16	2
CND-D	45	58H5	1	1.13	27.46	12.97	19.94	1
CND-D	45	58G4	1	1.17	18.73	7.05	5.78	2
CND-D	45	58J4	1	5.65	217.05	154.67		
CND-D	45	58H2	1	1.01	15.75	9.17	8.34	3
CND-D	45	58D2	2	24.00	438.21	276.80	258.26	5
CND-D	45	58G8-1	1	1.66	8.64	5.71		0
CND-D	45	58G8-2	1	1.07	6.25	3.19		0
CND-D	45	58G8-3	1	0.82	11.81	6.01		0

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	46	510A10	1	7.37	47.31	37.39	22.14	3
CND-D	46	510F7	1	2.09	33.76	20.02	27.66	1
CND-D	46	510I2	1	3.35	59.32	32.08	52.19	3
CND-D	46	510G2-1	1	0.98	12.54	6.09	8.76	2
CND-D	46	510G2-2	1	1.61	15.24	8.75	6.46	2
CND-D	46	510A2	1	6.17	43.57	30.89	21.99	3
CND-D	46	510B4	1	6.01	24.85	14.53	9.59	2
CND-D	47	512A9	1	1.19	27.28	17.18	27.28	1
CND-D	47	512A1	1	1.27	20.05	12.85	8.74	3
CND-D	48	514D9	2	6.76	124.44	44.09	81.06	3
CND-D	48	514I6	1	2.18	13.28	10.77	8.37	2
CND-D	48	514 E6	1	2.22	20.63	11.55	10.21	2
CND-D	49	516 E6	1	2.17	46.38	30.00	46.38	1
CND-D	49	516G3	1	7.20	47.93	30.95	29.06	2
CND-D	51	60D9	1	3.36	116.07	43.04	71.50	2
CND-D	51	60J5	1	1.95	50.85	20.39	16.98	2
CND-D	51	60I2	3	14.18	97.25	38.05	45.54	4
CND-D	51	60J1	1	2.15	19.80	9.64	10.52	2
CND-D	51	60F2	1	1.55	15.94	11.60	8.09	2
CND-D	51	60 E2	1	2.49	52.14	30.12	45.97	2
CND-D	52	62H9	1	2.35	42.51	24.35	36.25	2
CND-D	52	62 E8	1	3.16	68.88	42.98	40.57	3
CND-D	52	62H5	1	3.04	82.83	36.52	43.52	2
CND-D	52	62J1	1	5.28	101.03	30.99	101.03	3
CND-D	52	62A4	1	6.04	147.45	70.82	113.38	2
CND-D	53	64D6	1	1.81	22.84	8.46	13.83	2
CND-D	53	66A10	1	1.01	6.62	4.29		
CND-D	53	66G8	1	5.41	73.07	34.45	58.08	2
CND-D	53	66I7	1	1.45	24.98	11.00	8.83	3
CND-D	53	66H7	1	5.15	27.20	19.59	20.76	3
CND-D	53	66J6	1	7.32	72.77	37.41	33.90	2
CND-D	53	66 E7	2	13.79	153.72	67.82	119.64	5
CND-D	53	66J4	1	1.59	63.69	27.30	31.60	2
CND-D	53	66 E4	1	8.16	70.21	37.68	30.06	3
CND-D	54	66F1	1	1.12	35.59	11.02	8.14	3
CND-D	54	68A9	1		17.34	13.18		
CND-D	54	68D10	1		49.53	26.68		
CND-D	54	68H3	1	8.45	84.42	41.41	54.83	4
CND-D	55	68D3	1	3.28	54.51	25.50	19.98	2
CND-D	55	68D7	1	5.20	110.91	49.37	77.26	2
CND-D	55	68C5	1	6.34	46.74	22.79	19.54	2
CND-D	56	610 E9	1	3.43	65.78	29.30	31.38	3
CND-D	56	610A8	1		34.24	12.90		
CND-D	56	610A6	1		44.20	14.41	24.20	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	59	616B10	1	2.89	36.98	13.74	19.89	2
CND-D	59	616 E10	1	3.73	48.86	18.04	26.24	2
CND-D	60	618 E6	1	10.34	61.70	28.12	40.20	2
CND-D	60	618G5	1	1.60	15.40	6.99	7.53	3
CND-D	60	618H4	1	5.48	44.42	20.34	22.79	2
CND-D	61	70G10	1	6.98	70.22	37.26	38.06	5
CND-D	61	70I6	1	2.86	16.17	18.85	10.45	3
CND-D	61	70H5	1	2.62	40.41	24.81	32.36	2
CND-D	61	70H4	1	2.24	33.49	21.37	19.71	2
CND-D	61	70G4	1	1.82	17.73	5.79	10.51	2
CND-D	61	70 E4	1	2.26	63.32	28.86	44.31	3
CND-D	61	70I3	1	5.64	78.28	48.12	38.72	3
CND-D	61	70B3	1	2.06	22.63	13.08	12.02	3
CND-D	61	70C4	1	7.44	67.77	42.06	54.82	2
CND-D	61	70A4	1	3.46	88.12	60.84	58.16	3
CND-D	61	70B2	1	6.34	60.17	24.94	28.90	2
CND-D	61	70F1	1	2.39	30.99	18.36	27.92	1
CND-D	62	72A10	1	5.83	61.76	49.96	58.15	2
CND-D	62	72B10	1	7.44	78.95	44.86	49.44	3
CND-D	62	72I10	1	5.56	65.27	52.42	50.01	4
CND-D	62	72I8	1	6.80	47.83	22.29	36.23	2
CND-D	62	72J7	2	6.54	121.16	62.21	56.99	3
CND-D	62	72G7	1	7.84	78.42	46.78	38.13	2
CND-D	62	72D9	1		27.58	16.43	22.50	2
CND-D	62	72A8	2	6.15	89.00	80.19	51.99	4
CND-D	62	72B8	1	1.98	26.55	9.72	24.35	1
CND-D	62	72D8-1	1	2.96	32.97	10.44	8.02	2
CND-D	62	72D8-2	1	1.53	13.96	9.17	12.87	1
CND-D	62	72D7	1	2.92	45.87	13.45	45.87	1
CND-D	62	72C7	1	2.74	14.86	10.55	14.86	1
CND-D	62	72H6	1	7.92	41.26	39.88	33.84	2
CND-D	62	72I6	1	7.29	43.88	17.48	15.44	2
CND-D	62	72F6	1	5.97	236.21	43.48	146.06	2
CND-D	62	72B5	2	7.15	217.12	70.55	107.65	3
CND-D	62	72C5	1	6.92	62.40	54.23	62.40	2
CND-D	62	72I5	1	3.04	59.24	33.90	48.15	2
CND-D	62	72J4	1	2.04	18.76	13.11	13.67	2
CND-D	62	72G3	1	13.50	267.31	106.05	102.29	7
CND-D	62	72F4	1	1.42	11.80	5.32	11.80	1
CND-D	62	72B3	1	3.94	29.83	15.47	17.23	2
CND-D	62	72J2	1	3.99	23.59	17.42	18.77	2
CND-D	62	72 E2	1	8.80	184.89	89.83		
CND-D	62	72D2	1	2.19	10.82	8.87	6.82	2
CND-D	62	72C2	1	4.26	39.03	38.89	19.82	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	63	74I10	1	6.64	78.48	60.13	69.84	2
CND-D	63	74 E10	3	10.81	108.30	74.86	38.77	3
CND-D	63	74C9	3	10.49	153.87	105.37	107.19	4
CND-D	63	74B8-1	1	1.94	13.71	5.69	9.20	2
CND-D	63	74B8-2	1	1.59	38.61	18.00	11.22	2
CND-D	63	74 E8	1	8.91	129.22	44.96	91.41	2
CND-D	63	74J7	1	2.67	40.79	30.31	39.11	2
CND-D	63	74I7-1	1	4.62	25.71	14.50	16.45	3
CND-D	63	74I7-2	1	2.01	28.08	11.41	20.94	2
CND-D	63	74H7	1	3.87	20.58	10.41	17.62	1
CND-D	63	74F7	1	17.35	144.41	109.35	102.08	2
CND-D	63	74D7	1	2.09	23.20	8.94	18.34	1
CND-D	63	74D6	1	12.62	170.63	84.50	97.36	4
CND-D	63	74F8	1	21.74	117.50	59.45	78.78	2
CND-D	63	74I6	1	6.54	85.69	30.21	49.38	2
CND-D	63	74J6	1	3.02	81.90	50.53	45.37	2
CND-D	63	74C5	3	14.50	409.44	237.83	188.67	6
CND-D	63	74 E3	1	8.62	153.73	90.71	107.92	2
CND-D	63	74C3	1	0.58	8.23	1.08		0
CND-D	63	74F3	1	4.28	70.09	14.19	37.33	2
CND-D	63	74H3	2	5.00	105.01	58.99	49.23	4
CND-D	63	74I3	1	0.70	3.74	1.85		0
CND-D	63	74J2-1	1	1.68	25.41	15.90	21.73	2
CND-D	63	74J2-2	1	0.63	6.84	3.35		0
CND-D	63	74I2	1	0.43	5.57	1.31		0
CND-D	63	74C2	2	5.84	95.75	40.62	87.06	2
CND-D	63	74I1	1	3.75	13.41	8.89	8.34	2
CND-D	68	714D10	1	0.80	6.98	2.58		0
CND-D	68	714F10	1	1.63	22.85	13.60	10.34	2
CND-D	68	714C9	1	1.28	33.67	21.89	16.13	3
CND-D	68	714D8	1	2.43	38.45	26.21	22.69	3
CND-D	68	714G7	1	3.92	57.36	24.99	37.66	2
CND-D	64	76D10	1	7.87	99.24	83.31	64.49	3
CND-D	64	76C10	1		3.66	2.02		
CND-D	64	76F10	1	1.83	63.64	44.08	53.55	2
CND-D	64	76G10	1	8.72	83.04	43.60	64.24	3
CND-D	64	76J9-1	1	4.21	35.59	25.16	20.62	2
CND-D	64	76J9-2	2	5.43	36.41	22.83	36.41	2
CND-D	64	76J9-3	1	5.77	59.86	26.35	46.91	2
CND-D	64	76I9	1	1.85	16.27	8.06	11.98	2
CND-D	64	76H9	2	9.57	154.06	104.34	106.76	2
CND-D	64	76G9	1	6.63	91.04	29.68	48.31	2
CND-D	64	76C9	1	2.92	13.76	7.72	10.70	2
CND-D	64	76B9	1	7.65	68.64	23.26	30.54	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CND-D	64	76D8	3	24.37	240.06	154.07		
CND-D	64	76G7	1	3.82	15.37	22.18	13.47	3
CND-D	64	76H7	1	5.73	58.59	30.20	22.78	4
CND-D	64	76J7	1	4.47	38.81	15.27	22.13	2
CND-D	64	76H6	1	1.88	22.91	13.65	18.09	2
CND-D	64	76G6	1	0.91	2.59	1.62		
CND-D	64	76A5	1	21.79	408.66	253.24	277.27	2
CND-D	64	76D5	1	0.68	4.95	7.79		
CND-D	64	76F5	1	11.95	90.97	68.54	90.97	2
CND-D	64	76D3	1	1.08	8.06	4.22		0
CND-D	64	76 E2	1	0.88	6.91	2.12		
CNE-D	1	10B9	1	10.31	86.08	40.71	77.64	2
CNE-D	1	10B6	1	16.29	80.97	37.95	80.97	2
CNE-D	2	11 E10	1	1.48	25.58	20.24	12.70	2
CNE-D	2	11B9	1	6.32	71.99	64.87	39.07	3
CNE-D	2	11G6	1	1.24	69.10	30.41	34.39	3
CNE-D	2	11A5	1	7.23	113.56	76.97	71.17	3
CNE-D	2	11 E5	1	2.54	38.61	17.99	25.00	2
CNE-D	2	11H4	2	8.97	67.83	40.21	42.54	2
CNE-D	2	11F4-1	1	7.98	53.75	52.56	38.40	3
CNE-D	2	11F4-2	2	7.93	6.51	52.80		
CNE-D	2	11D4-1	1	1.43	12.92	9.10	8.80	3
CNE-D	2	11D4-2	1	2.84	36.75	28.46	16.99	2
CNE-D	2	11A4	1	1.49	15.77	8.79	8.49	2
CNE-D	2	11C3	1	4.48	24.40	23.30	19.31	2
CNE-D	2	11H2	1	4.57	15.81	11.58		
CNE-D	2	11 E2	1	13.27	140.13	117.99	107.72	3
CNE-D	2	11D2	1	13.57	99.63	65.20		
CNE-D	2	11B2-1	1	2.85	19.57	10.48	9.57	2
CNE-D	2	11B2-2	1	7.16	60.53	22.10	35.86	4
CNE-D	2	11A2	1	4.68	30.60	18.70	30.60	1
CNE-D	2	11J1	1	21.38	167.68	111.76		
CNE-D	2	11H1	1	4.86	48.59	26.82	45.06	2
CNE-D	2	11G1	1	1.67	19.87	18.60	13.66	2
CNE-D	2	11D1	1	5.58	27.91	18.41	16.35	3
CNE-D	3	12A10	1	16.62	94.09	48.99	33.54	4
CNE-D	3	12B10	1	0.54	6.13	2.73		0
CNE-D	3	12C10	1	2.52	15.20	10.41	6.92	3
CNE-D	3	12A8	1	2.08	13.37	8.09	4.51	3
CNE-D	3	12D8	1	13.17	56.69	47.97	56.69	2
CNE-D	3	12I7	1	6.39	56.80	51.07	53.78	3
CNE-D	3	12H7	1	7.53	63.63	33.14	63.63	3
CNE-D	3	12G7	2	6.93	96.82	49.37	96.82	1
CNE-D	3	12 E7	1	10.48	31.72	20.02	23.00	3

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	3	12A6	1	2.90	23.82	12.84	14.55	1
CNE-D	3	12F6	1	4.22	25.83	15.37	17.51	3
CNE-D	3	12H6	1	1.23	8.36	2.85	3.48	3
CNE-D	3	12I6	1	2.18	33.32	16.46	18.22	2
CNE-D	3	12J6	1	6.24	15.71	11.72		
CNE-D	3	12I5-1	1	4.82	13.35	10.55	5.89	2
CNE-D	3	12I5-2	1	2.92	15.83	6.32	7.92	2
CNE-D	3	12H5	1	15.55	94.09	46.62	94.09	3
CNE-D	3	12F5	1	6.32	28.88	22.81	15.67	2
CNE-D	3	12 E5-1	1	6.27	27.37	19.17	25.71	4
CNE-D	3	12 E5-2	1	11.23	45.68	33.60	24.39	3
CNE-D	3	12C4	1	15.85	117.85	110.60	87.49	6
CNE-D	3	12F4	1		81.57	62.98		
CNE-D	3	12H4	1	7.22	38.23	20.63	11.36	2
CNE-D	3	12G3	1	2.37	17.71	9.80	8.48	2
CNE-D	3	12F3	1	4.13	22.54	14.63	13.43	2
CNE-D	3	12B2	1	9.63	58.83	36.55	32.76	2
CNE-D	3	12I2	1	8.58	19.79	16.62	15.40	3
CNE-D	3	12G2	1	0.91	12.77	9.49	9.97	2
CNE-D	3	12G1	1	15.83	69.58	40.68	36.00	3
CNE-D	3	12F1	2	12.43	142.90	69.35	44.16	4
CNE-D	4	13B10	1	11.88	70.60	42.58	34.05	4
CNE-D	4	13C10	1	6.18	44.64	30.56	15.64	5
CNE-D	4	13G10	1	2.04	22.41	16.99	10.73	3
CNE-D	4	13H10	1	6.77	37.87	30.09	23.22	2
CNE-D	4	13I10	1		72.52	46.64		
CNE-D	4	13J10	1	2.82	22.91	17.69	16.51	3
CNE-D	4	13H9	1	2.54	26.02	20.76	26.02	1
CNE-D	4	13G9	1	10.61	62.38	39.09		
CNE-D	4	13F9	1	5.69	34.06	15.24	29.62	2
CNE-D	4	13 E9	1	7.45	52.03	31.16	33.04	2
CNE-D	4	13D9	1	8.10	53.40	23.49	36.56	6
CNE-D	4	13C9	1	5.08	33.78	19.02	27.73	2
CNE-D	4	13B9	1	8.25	116.00	49.50		
CNE-D	4	13C8	1	6.00	17.22	12.91		
CNE-D	4	13I8	1	5.94	80.32	31.61	43.49	2
CNE-D	4	13I7	1	4.57	53.69	34.66	18.81	3
CNE-D	4	13H7	1	11.15	124.47	68.29	89.57	4
CNE-D	4	13F7	1	6.87	33.15	11.11	18.09	2
CNE-D	4	13 E7	1	4.16	26.13	15.21	27.83	3
CNE-D	4	13B6-1	1	10.55	81.91	61.28	64.54	4
CNE-D	4	13B6-2	1	6.36	15.12	14.33	12.96	2
CNE-D	4	13D5	3	22.70	150.00	71.39	57.41	5
CNE-D	4	13H4	1	8.22	50.39	25.26	50.39	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	4	13F4	2	15.87	107.20	73.53	76.39	6
CNE-D	4	13D4	1	9.16	81.22	69.94	66.02	2
CNE-D	4	13B4	1	0.94	6.44	2.72	5.27	2
CNE-D	4	13B3	2	10.57	75.32	69.00	65.06	4
CNE-D	4	13B2	1	3.74	28.96	17.48	28.86	2
CNE-D	4	13 E2-1	1	3.83	32.56	17.25	14.24	3
CNE-D	4	13 E2-2	1	3.89	18.95	12.23	15.63	1
CNE-D	4	13I2	1	9.72	53.95	30.86	30.86	3
CNE-D	4	13H1	1	11.70	91.00	52.83	88.49	4
CNE-D	4	13G1	1	5.91	26.12	14.08	18.68	2
CNE-D	4	13F1-1	1	5.72	15.88	11.19		
CNE-D	4	13F1-2	1	3.20	21.62	13.82	20.03	2
CNE-D	4	13F1-3	1	4.33	22.68	17.19	22.16	3
CNE-D	5	20B10	1	14.41	126.09	67.48	68.87	7
CNE-D	5	20C10	2	11.77	55.76	34.95	39.95	3
CNE-D	5	20J9	1		18.20	14.01		
CNE-D	5	20F9	1	5.17	29.21	18.49	21.10	2
CNE-D	5	20A8	1	6.30	50.71	22.69		
CNE-D	5	20 E8	1	15.03	114.07	61.95		
CNE-D	5	20H8	1	13.97	254.86	134.35		
CNE-D	5	20J7	1	0.36	0.98	1.78		0
CNE-D	5	20D7	1	1.03	10.67	9.73	9.00	1
CNE-D	5	20C6	1		13.30	10.62		
CNE-D	5	20 E6	1	7.60	15.07	8.87	12.27	1
CNE-D	5	20F6	1	4.26	15.34	10.30	15.34	4
CNE-D	5	20H6	1	0.97	1.64	2.96		
CNE-D	5	20I6	1	1.20	3.79	4.17		
CNE-D	5	20F5	1	2.05	49.42	17.95	27.95	4
CNE-D	5	20 E5	1	2.55	34.95	22.58	26.69	2
CNE-D	5	20 E4	1	3.35	14.69	13.31	12.87	1
CNE-D	5	20G4	1	6.06	26.92	21.96	24.51	2
CNE-D	5	20I4	1	0.80	4.17	2.40		0
CNE-D	6	22A10	1	8.58	34.09	21.44	21.00	3
CNE-D	6	22D10-1	1	2.90	89.45	46.67	89.45	3
CNE-D	6	22D10-2	1	0.50	1.06	1.84		0
CNE-D	6	22H10	2	15.07	227.52	131.17	154.26	6
CNE-D	6	22J9	1	2.24	7.44	4.58	5.80	2
CNE-D	6	22J8	1	1.91	15.44	6.53	4.84	3
CNE-D	6	22G7	1	13.54	91.78	76.71	79.70	7
CNE-D	6	22 E7	1	4.15	29.73	18.30	19.35	2
CNE-D	6	22C7	1	3.06	10.27	7.59	11.59	1
CNE-D	6	22C6	1	5.17	13.87	9.00	9.60	2
CNE-D	6	22D6	1	3.78	32.89	12.58	12.55	2
CNE-D	6	22F6	1	5.12	22.86	14.35	17.11	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	6	22J5	1	1.40	23.14	16.78	21.38	1
CNE-D	6	22A5	1	11.44	65.30	50.00	41.51	3
CNE-D	6	22J3	1	4.02	15.98	6.94	5.70	2
CNE-D	6	22H3	1	1.09	5.39	4.45	5.19	1
CNE-D	6	22D3	1	2.83	32.68	28.77	25.11	3
CNE-D	6	22B3	1	5.61	23.02	12.05	18.92	2
CNE-D	6	22B2	1	4.07	20.72	13.49	10.72	2
CNE-D	6	22H2	1	19.41	91.53	69.61	59.45	6
CNE-D	6	22F1	1	3.49	30.28	17.61	14.21	2
CNE-D	6	22C1-1	1	3.96	35.94	21.35	17.51	3
CNE-D	6	22C1-2	1	11.02	47.16	31.97	42.28	3
CNE-D	7	24A10	1	5.69	28.48	18.55	18.10	3
CNE-D	7	24G9	1	3.74	34.13	23.23	19.74	4
CNE-D	7	24C9	1	13.82	127.12	59.50	127.12	2
CNE-D	7	24 E8	1	21.38	150.20	81.05		
CNE-D	7	24G8	1	17.02	69.01	39.10	42.10	3
CNE-D	7	24I8	3	9.59	76.08	64.12		
CNE-D	7	24I7	1	15.48	53.58	49.35	45.80	2
CNE-D	7	24C7	1	2.01	12.10	4.84	7.21	2
CNE-D	7	24A7	1	4.41	29.08	15.58	19.45	2
CNE-D	7	24C6	1	3.03	29.59	25.08	23.78	3
CNE-D	7	24D6	1	2.78	23.04	17.27	14.84	2
CNE-D	7	24G6-1	1	5.10	29.08	20.94	18.00	2
CNE-D	7	24G6-2	1	3.72	25.13	10.88	10.30	2
CNE-D	7	24H6	1	5.42	21.32	13.21	12.54	4
CNE-D	7	24J5	1	2.24	16.31	15.13		
CNE-D	7	24G4	1	14.43	97.48	55.40	57.00	4
CNE-D	7	24B3	1	6.91	90.38	59.09	49.24	2
CNE-D	7	24D1	1	2.14	25.00	16.67	19.01	2
CNE-D	8	30I8	1	6.61	37.72	18.13	19.39	3
CNE-D	8	30A4	1	14.67	126.55	80.15	81.16	3
CNE-D	8	30D4	3	12.89	93.45	65.72		
CNE-D	8	30F4	1	11.12	107.33	67.07	57.01	4
CNE-D	8	30J4	1	15.06	138.13	95.90		
CNE-D	8	30B3	1	12.77	149.99	127.76		
CNE-D	8	30D2	1	0.77	6.48	3.29		0
CNE-D	8	30I1	3	14.29	138.64	81.33	88.64	7
CNE-D	8	30G1	1	7.29	76.46	64.04	46.42	2
CNE-D	8	30 E1	1	1.70	15.84	9.87	11.35	1
CNE-D	8	30D1	1	5.23	29.88	18.37		
CNE-D	8	30A1	2	8.72	95.69	71.33	56.06	3
CNE-D	9	32C10	3	7.65	74.17	28.89	40.37	3
CNE-D	9	32 E10	1	6.57	69.12	46.75	49.76	3
CNE-D	9	32 E9	1	8.20	35.83	26.36	24.38	4

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	9	32J8	1	6.16	38.76	27.82	22.83	3
CNE-D	9	32G7	1	1.61	9.84	7.70	7.60	2
CNE-D	9	32B6	1	4.10	34.94	17.96	14.64	2
CNE-D	9	32B4	1	12.97	125.08	75.02		
CNE-D	9	32I3	2	29.85	153.75	84.12	74.47	3
CNE-D	9	32A2	1	15.93	144.21	82.96		
CNE-D	9	32F2	3	10.80	138.03	96.80	77.14	5
CNE-D	9	32G2	1	0.84	2.84	2.47		
CNE-D	9	32I1	1	13.67	134.42	68.50	76.55	4
CNE-D	9	32D1	1	19.58	107.04	50.19		
CNE-D	10	34C10	1	13.03	43.40	25.82	24.80	3
CNE-D	10	34D8	1	12.14	105.84	53.72	45.25	3
CNE-D	10	34C7	1	13.23	117.84	85.19	95.82	4
CNE-D	10	34 E7	1	9.75	34.38	16.83		
CNE-D	10	34D6	1	21.90	286.51	204.75	137.51	7
CNE-D	10	34I5	1	19.30	70.16	44.04	48.06	1
CNE-D	10	34F5	1	9.73	41.83	20.88	34.76	1
CNE-D	10	34A4	1	6.64	24.52	15.03	17.43	4
CNE-D	10	34G4	1	12.96	66.22	25.97	33.38	5
CNE-D	10	34J4	1	14.20	62.94	36.30	35.05	3
CNE-D	10	34I3	1	11.12	42.15	26.91	22.81	3
CNE-D	10	34B3	1	25.67	187.08	86.53	148.84	3
CNE-D	10	34C2	1	13.49	42.82	29.22	24.46	4
CNE-D	10	34F2	1	6.97	36.38	20.81	36.38	3
CNE-D	10	34J2	3	16.47	297.63	159.16	114.56	6
CNE-D	10	34G1	1	20.09	99.80	84.28	59.89	3
CNE-D	10	34F1	1	6.99	26.47	19.20	20.77	2
CNE-D	10	34D1	2	10.86	82.07	68.61	39.06	4
CNE-D	10	34C1	1	6.54	25.53	10.82	18.34	2
CNE-D	11	40D9	1	24.40	195.88	128.01		
CNE-D	11	40C7	1	12.77	286.42	127.92	119.24	5
CNE-D	11	40B4	1	16.82	154.04	80.49	79.85	4
CNE-D	11	40D4	1	10.48	34.16	32.87		
CNE-D	11	40C3	1	3.79	59.12	47.26	36.81	2
CNE-D	11	40J2	3	17.23	308.55	153.94		
CNE-D	12	42G10	1	5.67	78.74	37.72	33.33	3
CNE-D	12	42J10	1	10.47	87.15	79.08	56.61	1
CNE-D	12	42I9	2	11.72	52.55	28.77	39.96	2
CNE-D	12	42C9	1	12.11	71.15	57.54	41.27	7
CNE-D	12	42B9	1	4.15	40.50	12.37	31.25	1
CNE-D	12	42A9	1	2.66	29.06	11.10	18.61	2
CNE-D	12	42F8	3		261.05	112.47		
CNE-D	12	42J7	1	3.18	62.66	20.86	37.81	3
CNE-D	12	42I6	1	2.72	21.55	8.17	9.86	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	12	42F6	1	5.75	63.40	45.61	42.27	2
CNE-D	12	42A6	1	8.12	60.74	30.57	35.76	5
CNE-D	12	42C5	1	2.12	16.50	8.99		
CNE-D	12	42J5	1	2.97	20.00	15.78	17.71	1
CNE-D	12	42B4	2	5.98	35.58	18.55	20.42	2
CNE-D	12	42C3	1	2.11	21.94	14.25	13.18	2
CNE-D	12	42J3	2	14.37	107.38	89.44	105.42	5
CNE-D	12	42I2	1	11.98	104.69	68.36	51.98	4
CNE-D	12	42F2	1	2.73	44.64	26.59		
CNE-D	12	42 E2-1	1	1.48	26.83	16.76	14.78	2
CNE-D	12	42 E2-2	1	0.72	11.30	5.74		0
CNE-D	12	42B2	2	10.25	74.85	63.41	42.74	3
CNE-D	12	42G1	1	1.56	16.28	8.33	9.85	2
CNE-D	12	42D1	1	4.16	43.66	22.40	18.10	3
CNE-D	13	44B10	1	4.36	28.38	11.06	17.14	2
CNE-D	13	44C10	1	4.04	31.53	18.72	14.44	2
CNE-D	13	44D10	1	3.54	41.18	24.53	22.13	2
CNE-D	13	44G10-1	3	5.31	90.06	40.86	43.68	2
CNE-D	13	44G10-2	1	2.16	13.31	7.79	12.16	1
CNE-D	13	44I10	1	6.32	51.27	16.62	28.77	2
CNE-D	13	44 E9	1	2.77	27.99	10.77	21.48	1
CNE-D	13	44G8-1	1	12.00	86.78	43.73	63.67	3
CNE-D	13	44G8-2	1	0.40	3.49	2.74		
CNE-D	13	44F7	1	4.75	40.73	33.50	40.73	1
CNE-D	13	44D7	1	7.33	59.08	41.21	30.25	5
CNE-D	13	44C7	3	8.91	130.28	97.36	40.91	3
CNE-D	13	44A7	1	16.36	106.93	54.03	91.91	3
CNE-D	13	44B6	1	7.24	94.65	76.72	41.96	4
CNE-D	13	44H6	1	13.03	174.68	105.76	80.05	4
CNE-D	13	44G5	1	5.43	18.03	16.78	9.12	5
CNE-D	13	44D5	1	3.78	29.23	19.45	29.23	1
CNE-D	13	44B5	2	12.05	133.32	80.35	67.17	7
CNE-D	13	44A4	1	1.09	8.78	4.09	6.83	3
CNE-D	13	44B4	1	4.79	21.16	11.73	15.01	2
CNE-D	13	44G4	2	17.02	246.08	134.69		
CNE-D	13	44C3	1	7.19	41.54	39.81		
CNE-D	13	44B3	2	11.26	154.00	103.36	128.92	3
CNE-D	13	44B2	1	10.14	63.13	50.33	33.75	5
CNE-D	13	44J2	2	16.12	108.20	46.59	68.79	3
CNE-D	13	44D1	1	16.57	102.34	68.60	81.60	1
CNE-D	13	44B1	1	10.54	47.24	34.50	24.26	2
CNE-D	13	44A1	2	18.98	149.48	117.87	114.27	4
CNE-D	14	50J9	2	9.26	90.76	55.59	56.57	3
CNE-D	14	50H9	1	11.72	121.31	116.29		

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	14	50D9	2	7.15	309.01	117.21	153.81	4
CNE-D	14	50J7	1	1.73	18.67	15.43	18.67	1
CNE-D	14	50F6	1	2.88	42.19	18.93	27.24	3
CNE-D	14	50G6	2	7.13	96.56	55.11	57.31	3
CNE-D	14	50F5	1	4.52	62.48	35.91	62.48	1
CNE-D	14	50B4	1	7.33	28.94	22.52	39.74	3
CNE-D	14	50F4	1	3.62	46.31	28.97	46.31	2
CNE-D	14	50G5	1	6.55	137.98	64.30	68.94	5
CNE-D	14	50J4	1	0.80	4.87	4.86	4.38	2
CNE-D	14	50H3	1	6.62	148.03	42.86	88.62	2
CNE-D	14	50F3	1	2.42	11.36	10.32	6.45	2
CNE-D	14	50 E3	1	11.08	114.65	71.67	77.39	4
CNE-D	14	50C3	1	3.21	16.86	9.28	13.74	2
CNE-D	14	50D2	1	8.27	83.27	38.00	54.35	2
CNE-D	14	50J2	1	12.22	137.17	62.97	98.45	3
CNE-D	14	50F1	1	5.56	111.49	66.34		
CNE-D	14	50D1	1	2.24	11.43	7.68	9.04	1
CNE-D	14	50A1	1	10.24	95.83	50.89	58.83	2
CNE-D	15	52G10	1	7.02	38.97	32.54	38.97	2
CNE-D	15	52I10	1	5.28	79.52	50.15	70.30	3
CNE-D	15	52J10	1	9.17	47.94	28.39	49.46	2
CNE-D	15	52A8	1	14.88	79.23	51.99	41.71	1
CNE-D	15	52F8	1	8.62	77.88	35.83	62.77	2
CNE-D	15	52H8	1	8.19	58.18	54.77	41.69	2
CNE-D	15	52G8	1	7.03	42.72	42.63		
CNE-D	15	52G7	1	11.42	69.56	58.01	69.56	4
CNE-D	15	52A7	1	7.68	7.08	50.12	52.17	3
CNE-D	15	52C6	1	5.60	56.24	32.85	51.65	3
CNE-D	15	52G6	1	2.34	30.70	15.80	30.70	1
CNE-D	15	52F5	1	2.45	23.01	18.55	21.79	3
CNE-D	15	52C5	1	1.04	18.57	8.14	10.76	3
CNE-D	15	52I3	1	17.17	80.10	69.37	53.72	3
CNE-D	15	52J1	1	2.70	23.73	15.73	23.73	1
CNE-D	16	54A10	1	1.54	18.08	13.19	18.08	2
CNE-D	16	54C10	1	4.60	26.90	14.70	26.90	1
CNE-D	16	54F10	1	10.86	115.06	58.42	69.59	5
CNE-D	16	54G10	1	1.44	12.20	7.14	10.47	2
CNE-D	16	54H10	1	14.97	128.34	71.38	74.12	2
CNE-D	16	54J10	1	1.67	13.92	7.62		
CNE-D	16	54J9	1	15.52	77.56	56.71	50.22	4
CNE-D	16	54C8-1	1	0.60	2.59	2.14		
CNE-D	16	54C8-2	1	0.58	4.44	1.91		
CNE-D	16	54 E8	1	13.08	275.89	122.08	263.90	5
CNE-D	16	54J8	1	0.76	3.51	3.12		0

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	16	54H7	1	1.07	4.96	3.23		0
CNE-D	16	54A7	1	14.92	128.11	73.97	102.25	4
CNE-D	16	54H6	1	1.11	11.10	7.14	7.63	2
CNE-D	16	54I6	2	10.93	96.56	69.17	96.56	2
CNE-D	16	54J6	1	2.37	10.80	5.17	7.04	1
CNE-D	16	54G5	1	0.47	2.88	1.84		0
CNE-D	16	54F5	1	3.82	30.49	25.24	17.45	1
CNE-D	16	54 E5-1	1	1.28	8.77	4.87		0
CNE-D	16	54 E5-2	1	0.67	2.77	2.19		0
CNE-D	16	54D5	1	2.41	8.90	6.56	7.96	1
CNE-D	16	54C5	1		37.67	22.71		
CNE-D	16	54D4	1	14.06	12.97	72.61		
CNE-D	16	54H4	1	15.45	270.41	122.23	148.77	3
CNE-D	16	54I4	1	8.78	74.57	68.80		
CNE-D	16	54H3	1	1.26	15.65	8.35	9.47	2
CNE-D	16	54F3	1	3.82	21.99	14.43	17.80	4
CNE-D	16	54D3	1	2.40	21.82	8.54	19.47	3
CNE-D	16	54B3-1	1	4.50	34.30	19.10	12.40	3
CNE-D	16	54B3-2	1	0.76	3.50	1.81		0
CNE-D	16	54A3	1	4.59	42.12	22.12	24.28	3
CNE-D	16	54 E2	1	1.53	29.34	29.44		
CNE-D	16	54F2	1	0.92	3.43	1.57		0
CNE-D	16	54C1	1	1.75	10.47	9.25	8.38	3
CNE-D	17	60 E10	1	11.47	114.97	43.72	69.89	2
CNE-D	17	60B9	1	11.73	153.95	102.05	129.00	3
CNE-D	17	60J8	1	6.48	20.68	13.48	20.25	1
CNE-D	17	60I8	1	5.02	36.53	20.97	22.23	4
CNE-D	17	60F8	1	10.30	80.61	43.31	80.61	2
CNE-D	17	60B8	1	8.07	52.24	24.14	34.08	1
CNE-D	17	60D7	1	4.22	21.47	13.47	12.99	2
CNE-D	17	60J6	1	11.18	66.28	33.21	50.73	3
CNE-D	17	60I6	1	6.68	114.03	43.69	114.03	2
CNE-D	17	60G6	1	1.91	18.83	18.02	12.22	2
CNE-D	17	60F6	1	1.00	7.64	13.12		
CNE-D	17	60D6	1	7.48	55.11	26.35	41.75	1
CNE-D	17	60F5	1	3.37	28.64	11.19	23.19	2
CNE-D	17	60F3	1	6.86	125.34	53.17	111.69	2
CNE-D	17	60 E2	1	4.11	76.89	59.21	51.32	3
CNE-D	17	60B1-1	1	6.80	24.16	18.32	19.04	1
CNE-D	17	60B1-2	1	0.42	5.01	4.19		0
CNE-D	18	62F10	1	20.59	293.32	94.28	185.66	4
CNE-D	18	62 E9	1	4.43	21.43	13.55	14.64	2
CNE-D	18	62C8	1	5.04	36.20	24.23	17.26	3
CNE-D	18	62A8	1	12.52	107.60	76.61	72.95	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	18	62I7	1	3.30	18.58	10.00	12.73	3
CNE-D	18	62G7	1	1.76	24.35	18.07	24.17	2
CNE-D	18	62F6	1	7.02	47.90	53.18	37.10	5
CNE-D	18	62H6	2	6.16	53.10	35.50	41.65	4
CNE-D	18	62I6	1	4.67	52.59	14.57	26.62	4
CNE-D	18	62H5	2	9.93	64.70	33.85	47.62	2
CNE-D	18	62G5	2	9.36	59.34	41.98	40.51	4
CNE-D	18	62B5	1	14.84	84.45	52.69	46.12	3
CNE-D	18	62C4	2	16.50	206.42	92.77	105.33	4
CNE-D	18	62 E4	1	1.12	18.34	10.38	18.34	1
CNE-D	18	62J4	1	1.05	14.96	14.01	13.81	1
CNE-D	18	62H3	1	9.24	65.30	37.89	32.54	5
CNE-D	18	62G3	1	8.53	36.26	24.96	32.29	3
CNE-D	18	62C3	2	18.18	64.68	38.71	49.08	2
CNE-D	18	62A3	1	0.89	8.53	4.29		0
CNE-D	18	62H2	1	4.86	23.42	13.22		
CNE-D	18	62I2	1	9.01	123.55	60.85	106.86	3
CNE-D	18	62F1	1	1.34	24.63	13.03	22.27	2
CNE-D	18	62 E1	1	4.66	28.11	20.19	17.18	2
CNE-D	19	64D10-1	1	2.22	18.29	10.97	12.73	2
CNE-D	19	64D10-2	1	4.29	23.29	13.30	11.78	2
CNE-D	19	64H10	1	3.74	17.71	12.69	12.24	2
CNE-D	19	64J10	1	3.23	47.36	21.78	24.38	2
CNE-D	19	64H9	1	6.72	36.92	27.05	36.92	2
CNE-D	19	64A8	1	22.30	252.40	117.48	88.50	9
CNE-D	19	64I7	1	0.47	7.49	5.38		0
CNE-D	19	64I6	2	23.50	308.12	134.49	229.37	5
CNE-D	19	64 E6	2	7.20	73.96	47.53	57.32	2
CNE-D	19	64 E5	1	4.58	35.22	16.99	21.94	1
CNE-D	19	64J4	1	5.00	30.24	16.41	11.72	3
CNE-D	19	64H4	1	3.33	20.15	14.13	11.90	3
CNE-D	19	64F4	1	1.75	21.53	11.09	11.33	2
CNE-D	19	64B4	1	11.36	79.07	65.19	53.90	3
CNE-D	19	64G3	1	4.53	21.56	10.95	13.18	2
CNE-D	19	64C2	1	0.82	7.48	3.82		
CNE-D	19	64B3	1	9.47	65.95	31.49	37.23	2
CNE-D	19	64J2	1	11.80	59.14	56.39	46.41	3
CNE-D	19	64C1	1	9.16	23.82	15.84		
CNE-D	20	70A10	1	1.02	24.53	21.51	12.11	4
CNE-D	20	70B10	1	6.24	82.65	29.37	82.65	2
CNE-D	20	70I10	1	7.49	56.82	33.69	21.06	4
CNE-D	20	70G9	1	5.32	41.76	18.69	15.58	4
CNE-D	20	70A8	1	0.42	2.52	1.01		0
CNE-D	20	70J8	1	16.02	209.62	102.31		

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	20	70 E7	1	18.16	100.68	52.54	67.84	3
CNE-D	20	70B6	1	0.98	3.05	2.03		0
CNE-D	20	70A5	1	7.60	119.48	42.50	76.31	3
CNE-D	20	70B4	1	5.88	62.10	44.92	30.05	6
CNE-D	20	70I3	1	9.54	196.57	135.78	100.15	4
CNE-D	20	70B2	1	4.88	24.22	18.07	15.54	3
CNE-D	21	72C10	1	6.67	119.09	68.20	67.51	4
CNE-D	21	72F10	1	9.10	131.10	115.80	78.82	3
CNE-D	21	72I10	1	2.72	19.63	12.53	12.20	2
CNE-D	21	72H9-1	1	8.26	43.49	24.97	32.66	2
CNE-D	21	72H9-2	1	2.99	11.61	9.84		
CNE-D	21	72B8	1	2.43	15.09	12.58	11.55	2
CNE-D	21	72F8	1	10.49	108.86	92.73	90.02	3
CNE-D	21	72G8-1	1	0.37	3.88	3.25		0
CNE-D	21	72G8-2	1	0.49	3.54	2.28		0
CNE-D	21	72I8	1	18.51	207.47	115.58	143.40	5
CNE-D	21	72I7	1	4.16	28.03	17.11	25.50	3
CNE-D	21	72B6	1	0.85	4.02	3.56		0
CNE-D	21	72D6	1	12.70	244.66	106.65	128.90	5
CNE-D	21	72F6	1	3.05	24.90	15.58	24.90	1
CNE-D	21	72H6	1	9.01	125.32	58.25	75.50	3
CNE-D	21	72B5	1	4.00	20.76	18.58	13.10	2
CNE-D	21	72A5	2	8.61	114.87	51.65	74.12	3
CNE-D	21	72 E4	1	1.06	27.64	15.34	15.21	2
CNE-D	21	72G4	1	11.43	86.42	35.77	50.59	2
CNE-D	21	72 E3	1	0.58	3.35	3.07		0
CNE-D	21	72C3	1	12.89	110.03	43.39	70.71	3
CNE-D	21	72B3-1	1	4.54	42.53	26.53	42.53	1
CNE-D	21	72B3-2	1	5.85	74.12	12.56	51.22	2
CNE-D	21	72A2-1	3	7.99	55.65	38.90	36.55	4
CNE-D	21	72A2-2	1	8.59	84.57	48.75	69.97	3
CNE-D	21	72C2	1	4.36	27.87	28.91		
CNE-D	21	72F2	3	3.99	25.68	17.46	18.47	3
CNE-D	21	72G2	1	1.04	14.16	6.61	11.53	1
CNE-D	21	72H2	1	11.96	128.05	73.53	88.71	3
CNE-D	21	72I2	2	7.01	43.82	40.45	33.46	2
CNE-D	21	72J1	1	19.37	75.22	50.84		
CNE-D	21	72G1	1	9.69	63.19	25.59	63.19	1
CNE-D	21	72 E1	1	3.12	26.85	15.78	22.10	2
CNE-D	21	72D1-1	1	4.66	31.53	19.18		
CNE-D	21	72D1-2	1	0.79	13.08	13.25		
CNE-D	21	72C1-1	1	8.21	60.68	42.73	40.88	2
CNE-D	21	72C1-2	1	2.74	72.42	26.01	60.52	2
CNE-D	21	72A1	1	7.83	22.77	11.44	22.77	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
CNE-D	22	74B10	1	1.23	19.40	11.79		
CNE-D	22	74C10	1	2.17	10.82	8.88	7.00	1
CNE-D	22	74H10	1	5.39	89.39	67.88	59.39	2
CNE-D	22	74I10	1	1.39	40.30	6.97	27.47	1
CNE-D	22	74I9	2	9.07	64.13	42.95		
CNE-D	22	74F8	1	2.42	21.00	12.35	10.28	2
CNE-D	22	74A7	1	1.34	19.72	8.21	19.72	1
CNE-D	22	74B7	1		23.78	13.33		
CNE-D	22	74D6	1	0.52	13.22	8.34	10.04	2
CNE-D	22	74 E6	1	1.82	29.68	14.28	19.62	3
CNE-D	22	74D5	1	14.57	285.82	116.27	138.13	4
CNE-D	22	74B5	1	0.48	5.02	1.20		
CNE-D	22	74G4	1	7.48	196.64	148.42	111.38	5
CNE-D	22	74I7	1		70.35	24.41		
BHN-N	1	10C10	1	9.73	296.97	66.29	140.80	2
BHN-N	1	10D10	1	9.44	52.66	42.45	44.38	2
BHN-N	1	10H10	3	4.19	75.60	40.34	49.27	4
BHN-N	1	10C9	1	3.86	152.85	108.72	99.81	4
BHN-N	1	10G8	3	7.11	75.52	51.05	120.27	4
BHN-N	1	10F6	1	5.24	154.06	108.49	95.21	5
BHN-N	1	10I5	1	4.19	52.60	20.42	35.42	3
BHN-N	1	10F5	1	4.34	50.21	27.01	35.82	3
BHN-N	1	10I4	1	3.99	47.92	31.42	25.93	3
BHN-N	1	10C2	1	1.69	27.75	8.34	27.75	1
BHN-N	2	12B9	1	9.90	95.41	56.88	82.54	2
BHN-N	2	12A8	1	5.78	44.90	36.75	42.15	2
BHN-N	2	12D8	1	7.01	121.70	44.13	63.76	1
BHN-N	2	12F8	1	2.19	21.68	16.17	13.56	3
BHN-N	2	12I6	1	3.57	77.08	35.41	54.12	2
BHN-N	2	12D4	1	1.69	5.17	8.73		
BHN-N	2	12F3	1	9.80	153.88	125.45	124.74	2
BHN-N	2	12B3	1	7.45	102.97	73.62	84.16	3
BHN-N	2	12B1	1	3.29	54.89	36.86	38.59	2
BHN-N	3	14B9	2	5.45	120.96	61.40	90.01	2
BHN-N	3	14F7	1	5.22	83.64	39.92	59.93	3
BHN-N	3	14 E7	1	3.17	40.59	16.64	19.14	2
BHN-N	3	14 E6	1	4.82	38.20	29.86	24.42	1
BHN-N	3	14B5	1	1.23	21.24	12.71	10.95	2
BHN-N	3	14B4	2	6.69	118.56	96.58	112.26	3
BHN-N	4	16A8	3	6.53	272.03	102.58	154.11	6
BHN-N	5	18I8	1	6.43	154.09	149.38	87.09	3
BHN-N	5	18J3	1	11.15	102.52	65.27	76.70	1
BHN-N	6	110F10	1	4.92	37.19	21.05	25.71	4
BHN-N	6	110H9	1	1.91	31.19	18.74	29.35	2

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BHN-N	6	110F9	1	11.01	153.99	116.42	142.65	4
BHN-N	6	110H7	1	2.94	154.00	59.50	105.19	3
BHN-N	6	110G5	1	9.83	154.01	76.42	106.76	3
BHN-N	6	110F5	1	7.99	47.65	26.53		
BHN-N	6	110D4	1	4.69	36.80	23.32	32.58	2
BHN-N	6	110 E4-1	1	3.05	43.87	22.23	43.87	1
BHN-N	6	110 E4-2	1	3.45	33.81	17.73	22.53	2
BHN-N	6	110F3	1	6.98	382.80	116.16	137.04	2
BHN-N	6	110H2	1	4.29	62.16	36.62	62.16	1
BHN-N	7	112D10	1	1.67	14.97	10.37	13.37	2
BHN-N	7	112G10	2	7.03	121.77	50.33	67.79	3
BHN-N	7	112H9	3	9.14	126.01	63.04	86.25	2
BHN-N	7	112F8	1	1.61	31.82	13.48	31.82	1
BHN-N	7	112A8	1	1.13	8.10	5.54		
BHN-N	7	112H7	1	5.01	58.62	28.94	58.62	2
BHN-N	7	112I5	1	3.03	36.28	25.79	27.32	2
BHN-N	7	112G5	1	1.74	21.04	13.84	6.37	3
BHN-N	7	112 E3	2	5.84	122.00	56.00	52.00	3
BHN-N	7	112H1	1	7.90	87.80	39.50	54.10	2
BHN-N	7	112G1	1	4.90	31.00	21.50	25.10	2
BHN-N	8	114C10-1	1	1.00	5.50	4.00		
BHN-N	8	114C10-2	1	3.50	45.80	33.40	26.00	2
BHN-N	8	114H10	1	3.15	43.18	23.90	12.07	2
BHN-N	8	114I10	1	5.02	46.18	28.11	27.11	3
BHN-N	8	114J9-1	1	3.10	110.43	80.32	90.36	2
BHN-N	8	114J9-2	1	3.10	62.40	31.20	62.40	1
BHN-N	8	114H9	1	2.10	12.05	7.03	8.04	3
BHN-N	8	114 E9	1	2.01	41.16	13.50	41.16	2
BHN-N	8	114B6	1	1.00	9.04	4.02		
BHN-N	8	114H5	2	5.02	108.43	72.28	47.19	2
BHN-N	8	114A4	1	2.01	21.80	10.04	16.06	2
BHN-N	8	114A3	1	1.00	14.06	5.02		
BHN-N	8	114 E2	1	4.02	51.95	39.15	39.15	2
BHN-N	8	114F1	1	5.02	106.42	63.25	83.20	2
BHN-N	8	114A1	1	3.15	99.39	52.00	99.39	1
BHN-N	9	117B10	2	7.25	142.31	61.47	93.65	3
BHN-N	9	117 E10	1	1.23	29.03	7.41	16.20	2
BHN-N	9	117H10	1	2.20	27.93	13.32	14.19	3
BHN-N	9	117A7	1	7.94	91.89	78.50		
BHN-N	9	117 E6	1	0.58	5.05	2.68		0
BHN-N	9	117I4	1	1.49	20.85	8.73		
BHN-N	9	117I3	1	0.60	4.22	2.94		0
BHN-N	10	120B10	1	5.62	68.89	56.42	41.08	3
BHN-N	10	120A7	1	5.13	101.14	58.87	81.92	7

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BHN-N	10	120C6	1	6.28	132.85	68.38	132.85	2
BHN-N	10	120J4	1	8.70	66.08	35.17		
BHN-N	10	120H4	1	2.35	41.07	22.23	23.44	2
BHN-N	12	30D9	1	4.58	60.81	36.31	60.81	4
BHN-N	12	30A4	1	6.05	309.14	133.86		
BHN-N	13	33H4	1	3.96	41.22	22.79	41.22	3
BHN-N	13	33G1	1	6.13	151.55	98.90	92.06	2
BHN-N	13	33 E1	1	1.22	15.04	7.62	15.04	2
BHN-N	16	312I7	1	4.83	153.97	21.99	153.97	1
BHN-N	16	312I4	1	2.75	154.16	48.31		
BHN-N	16	312H3	1	5.10	68.30	50.02	68.30	2
BHN-N	16	312D2	1	2.28	23.97	12.36		
BHN-N	16	312D1	2	5.94	121.60	75.04	58.42	3
BHN-N	16	312C1	1	2.17	12.03	7.19		
BHN-N	18	315J3	2	10.50	116.95	60.64		
BHN-N	17	318B9	3	9.95	100.79	38.43	100.79	2
BHN-N	17	318F5	1	4.27	118.28	58.35	118.28	1
BHN-N	17	318C5	1	1.10	16.29	9.06	16.29	1
BHN-N	17	318H4	1	7.49	118.16	57.74		
BHN-N	19	321J8-1	1	10.18	91.65	35.75	91.65	2
BHN-N	19	321J8-2	1	12.50	95.29	30.37	69.90	2
BHN-N	19	321H7	1		52.30	22.20		
BHN-N	19	321D4	1	3.58	154.11	61.03	131.82	2
BHN-N	20	324A10	1	10.47	189.71	80.96	189.71	4
BHN-N	20	324B9	1	6.25	90.28	28.22	90.28	1
BHN-N	20	324C9	1	12.04	52.52	44.09	52.52	2
BHN-N	20	324C7	1	5.63	126.03	121.38	126.03	2
BHN-N	22	50 E5	1	1.39	33.48	15.86	33.48	1
BHN-N	22	50I2	1	2.44	35.50	19.33	21.48	2
BHN-N	23	53F10	1	4.23	40.32	13.26	15.39	3
BHN-N	23	53G10	1	6.28	89.00	57.77	89.00	1
BHN-N	23	53H10	1	3.50	35.17	19.50	35.17	2
BHN-N	23	53J10	1	6.12	72.11	27.66	72.11	2
BHN-N	23	53I9	1	5.17	126.80	82.16	96.23	2
BHN-N	23	53G8	1	4.45	34.35	17.39		
BHN-N	23	53I3	1	5.30	154.13	92.89	96.31	2
BHN-N	23	53J1	1	7.35	108.43	69.47	108.43	1
BHN-N	23	53A1	1	4.39	64.40	24.53	64.40	1
BHN-N	25	59I9	1	5.06	68.21	30.98	68.21	3
BHN-N	25	59H9	1	4.31	101.66	39.41	101.66	1
BHN-N	25	59G6	1	5.94	42.75	26.63	42.75	2
BHN-N	25	59D1	1	4.62	27.27	17.37	27.27	2
BHN-N	26	512 E10	1	3.35	46.97	18.17	46.97	1
BHN-N	26	512G10	1	2.76	27.45	18.06	9.05	1

Table AV.II (Continued) Morphological data for *S. jejuna*

Site	Plot No	Location	Sex	BD (mm)	L (mm)	W (mm)	LB (mm)	# Branches
BHN-N	26	512G9-1	1	2.71	12.15	6.93		
BHN-N	26	512G9-2	1	3.19	32.91	9.62	21.57	2
BHN-N	26	512H8	1	5.00	86.22	56.72	48.01	3
BHN-N	26	512G1	1	5.35	46.62	26.97	46.62	2
BHN-N	26	515 E10	1	5.40	210.52	139.58	126.12	4
BHN-N	26	515H10	2	6.08	144.56	66.35	144.71	2
BHN-N	26	515G8	2	5.67	73.18	55.71	55.42	2
BHN-N	26	515C1	1	2.81	23.16	12.21	10.60	3
BHN-N	28	518C6	1	2.98	21.91	12.40	8.40	3
BHN-N	28	518D6	1	1.75	23.42	9.91		
BHN-N	29	521A10	3	9.84	126.17	96.18	93.28	2
BHN-N	29	521B9	1	2.79	51.53	36.31	51.53	1
BHN-N	30	524H7	1	9.37	115.80	41.18		
BHN-N	30	524A7	1	4.72	30.26	12.36	19.06	2
BHN-N	30	524B7	1	4.91	24.34	15.58		
BHN-N	30	524D7	1	3.26	46.91	18.84	46.91	1
BHN-N	30	524B5	1	4.69	93.74	39.24	50.97	3
BHN-N	30	524C5	1	3.20	68.41	21.02		
BHN-N	30	524 E3	1	5.51	105.07	62.69	48.68	3

APPENDIX VI: Photographic illustrations of *S. jejuna* and the limestone barrens of Newfoundland

Figure AVI.I *Salix jejuna* (Female) at Cape Norman (Site CNA-N), on the limestone barrens of the Great Northern Peninsula of Newfoundland; Photo taken June, 2006 by J. Robinson.

Figure AVI.II Limestone barrens (natural) at Cape Norman (Site CNA-N) on the Great Northern Peninsula of Newfoundland; Photo taken July, 2006 by J. Robinson.

Figure AVI.III Limestone barrens (natural) at Boat Harbour (Site BHN-N) on the Great Northern Peninsula of Newfoundland, along the coast of the Strait of Belle Isle; Diane Pelley and Gina Whelan; Photo taken May, 2007 by J. Robinson

Figure AVI.IV Anthropogenically-disturbed limestone barrens Cape Norman (Site CND-D) on the Great Northern Peninsula of Newfoundland, along the coast of the Strait of Belle Isle; Photo taken June, 2006 by J. Robinson.