Proceedings of the 7th Annual Thompson Rivers University

Undergraduate Research and Innovation Conference

Kamloops, BC | April 2012



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Introduction

Thompson Rivers University Undergraduate Research and Innovation Conference and its annual Proceedings constitute a forum for TRU undergraduate researchers who work on various projects, case studies, research papers, professional, artistic, and other scholarly and innovative works year-round covering a diverse range of topics of their choice.

Through this collection of selected articles presented to the 2012 Thompson Rivers University Undergraduate Conference we recognize and broadcast not only the accomplishments of the recent past, but of our collective future. Each of these articles represents for these young researchers both the culmination of a long intellectual process and expectations regarding what needs to be addressed next. From first defining a topic of interest, researching that topic, writing up results, presenting the findings in an open forum, to revising and editing for final consideration in this collection, these TRU students have brought attention and depth to their particular subject area, but more importantly, defined the terms and established the grounds for further research and academic debate moving forward in this century. The breadth and significance of the themes addressed may readily be seen in the following abstracts.

Four of the contributions to this collection directly address themes specific to the fate of our country. Amber Wilson, in "Back to the Pantry: Canada's Truth is in the Cupboard" grapples with the illusive yet passionate debate over what constitutes the "Canadian identity," seeking insight and revelation through literary humour and orality as the means by which to establish a new understanding of "being Canadian." Exploring new avenues in interrogating this theme, Wilson provides strong grounds for a much more imaginative and Each of these articles represents for these young researchers both the culmination of a long intellectual process and expectations regarding what needs to be addressed next.

Through these articles our undergraduate researchers have addressed topics as varied as the construction of national identity, cultural survival. representations of war, community revival, local and global economic stability, food security, global warming, and biodiversity.

evocative approach to understanding our identity. In "Canadian Afghanistan War Artist: Canadian Forces Artists Program (CFAP)," Natasha Costello, through the art of Karen Bailey, draws attention to the fact that in 1916 Canada was the first country in establishing a war art program that allowed for civilian artists to work alongside Canadian soldiers on both domestic and oversea operations, and how the revival of this program in 2011 has ushered in a new era of Canadian military art. Costello's profile of the work of Karen Bailey, which focused on painting under-recognized members of society in Afghanistan at the Triage Hospital, based at the Kandahar Air Field (KAF), serves to remind us of the difficult and hazardous context to which numerous Canadians and Afghanis were recently subject. Based in part on direct communications with the artist, Costello directs us to the inspiration for these works, and how this art will immortalize the immense sacrifices and shape our understanding of our role in the globe. Saskia Perriard-Abdoh, in "An Overview of the Great Expulsion, Subsequent Migrations and Acadian Cultural Persistence" provides an overview of the historical context preceding the Great Expulsion which took place in 1755, and the resulting Acadian population movements and their impact on the surrounding landscape. Perriard-Abdoh, noting that while ancestral lands and ways of life were irrevocably lost, instead of assimilating into their surroundings many Acadians retained their values and adapted to their surroundings as indicated by the renewal of Acadian culture that can be observed in the present-day Maritimes and Louisiana-a testament to the strength and resilience of the Acadian people and their culture to the present, and a compelling account of how cultures adapt and survive in novel ways. In "Increasing Community Economic Development - Report in Duncan: Strategies for

Seniors, First Nations Partnerships, and the Creative Economy" Bonnie Klohn provides a background and context to some of the strategies Duncan has already undertaken to revive the fortunes of this community, then further examines new innovative strategies that are emerging in the community economic development, planning and creative economy literature. Using the insights from this literature Klohn advances novel ideas for this small city to attract retirees and new immigrants, benefit from the care of seniors, and strengthen community and economic links with First Nations, delving into new possibilities to retain and attract young people in an effort to rejuvenate a community confronted with economic and population decline, ideas that may benefit many towns and small cities across Canada struggling with similar situations.

Three of the papers in this collection address pressing global themes. In "Value of Residential Building Permits for Single Family Dwellings in Canada: What does the future hold?" Christina Smale, recognizing that there has been very little research in developing a forecast model to predict the value of residential building permits, has initiated research to develop a model that will produce an accurate and reliable forecast of the value of residential building permits for single family dwellings in Canada. Smale's testing of various models is premised on the insight that the successful forecasting of the permit values in Canada could lead to understanding how these values change over time and what impacts these values, leading to the ability to anticipate economic expansions and contractions. In "Does Convergence Theory Help to Explain Resiliency after Land Reform in Mexican Ejidos?" Bonnie Klohn utilizes the theory of convergence - suggesting that when a regional economy's needs converge with the goods and services its producing, a more stable and resilient economy results - to understand and evaluate the prospects for positive outcomes from the dramatic land-use changes emerging in the Mexican countryside under NAFTA with the dismantling of the Ejido communal land-holding structure. Klohn's examination of various cases draws attention to the potential devastating effects on local food production and local economic stability arising from increased integration due to free trade agreements. The issue of global warming and how this may be addressed is examined by Cody Ponting in "CO2 Sequestration Using Continuous Microalgae (Chlamydomonas sp.) Culture Linked in Series." Ponting posits that by developing a system that is capable of sequestering CO₂ emissions by use of modified algal bioreactors, it would be possible to eliminate current methods that are often counter productive. For Ponting the overall purpose of this study is to develop a small-scale model that can be transitioned to an

industrial application in hopes of reducing the high levels of gaseous carbon dioxide in our atmosphere.

Two studies for this collection offer in-depth examinations of the difficulties of determining either the reproductive processes or the reproductive health of the plant world that surrounds us. In "Does inbreeding depression occur in the Sagebrush Buttercup (Ranunculus glaberrimus)?" Sabina Donnelly observes that inbreeding depression should be considered a growing threat to population stability as habitat fragmentation due to anthropogenic activities makes reproduction via out-crossed pollination rarer and more difficult to achieve. Noting that while the results of this research have provided only limited evidence that reproductive mode, year of production and type of flower substantially affects germination, Donnelly states that the results have revealed potential avenues for future work. Kristin Tilbury, in "Analysis of Optical Response and Morphological Dimorphisms of Gender Morphs in an Androdioecious Population of Ranunculus glabberimus ssp. Ellipticus," analyzes visual cues including abundance of reproductive parts, and petal reflectance, and compare these analyses to the frequency of male occurrence within the Lac du Bois population in order to determine if male flowers rely on unique visual cues to promote pollinator visits, and in an attempt to elucidate a correlation between abundance of sexual morphs and dimorphism of petal reflectance in this rarely observed system. Tilbury observes that additional research with this population could result in the identification of the visual, olfactory, or combination of visual-olfactory cues that maintain this population and could also elucidate a correlation between the gender dimorphism and specific inherited or genetic trait or traits. Both researchers advance keen insights into new methods and techniques that may be incorporated into future research to establish more conclusive results to open up our understanding of the natural world.

Through these articles our undergraduate researchers have addressed topics as varied as the construction of "national identity," cultural survival, representations of war, community revival, local and global economic stability, food security, global warming, and biodiversity.

Having had the opportunity to not only organize this conference and supervise research projects, but to view many students' presentations and evaluate research poster displays, we can attest to the incredible pride, enthusiasm and knowledge of all the students who participated in this conference. Further recognition must be bestowed upon all the research supervisors, faculty, administrators and support staff who contributed to this outcome, for as Kristin Tilbury remarks in her article "This work has been incredibly interesting...and further work would be incredibly rewarding, thank you very much for the opportunity." Consistent with our own experiences, we are all confident that none of these time-consuming research papers could be in its current stage without the help of the dedicated and committed faculty supervisors. These faculty mentors not only put their students first, but have also shown that TRU is a true place for undergraduate research. Additionally, we are pleased that with the supports of TRU Provost and Vice-President Academic, the dedicated undergraduate faculty research mentors, Associate Vice-President Research, Deans, and the supportive team of Research, Innovation and Graduate Studies Office, this conference and its annual Proceedings have undoubtedly secured TRU's reputation in the area of undergraduate research in Canada.

Finally, more than just what we can learn at this moment about our world, this conference and these articles are a testament to our prospects for the future. And our future is in good hands.

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Back to the Pantry: Canada's Truth is in the Cupboard

Amber Wilson

English and Modern Languages

Supervisor: Ginny Ratsoy

In 2007 Andrew Cohen, a journalist, wrote: "The Canadian Identity, as it has come to be known, is as elusive as the Sasquatch and Ogopogo. It has animated—and frustrated—generations of statesmen, historians, writers, artists, philosophers, and the National Film Board" (3), not to mention a multitude of students. Canadians are supposed to define themselves and identify with how they are defined by others— as the "mosaic" of culture: a stew of ethnic, religious, political and historical ingredients poured into a bowl and stirred with an assumptive spoon. Here's the thing— to the average Canadian, the stew tastes awful. For the most part, we don't want stew. We want separate ingredients that each of us may do different things with whether it results in a soup, salad, sandwich, or soufflé: to create a dish, to write our own recipes, to taste palatable. If each of us want to be our own amalgamation of ingredients, it is difficult to see how Canada could identify with a particular dish. Perhaps that's the point; perhaps we are a buffet designed to please everyone, or better yet, perhaps we are a cookbook full of possibilities.

In Canada's struggle to claim an independent cultural identity— a vernacular that stands apart from the metanarrative of traditional cultural stereotypes— there are a substantial number of authors that have attempted to define what it is to be Canadian through literature. Robert Kroetsch has grown a new prairie poet intent on moving beyond the parameters of a regular farm life in *Seed Catalogue*, George Bowering has re-written the dominantly patriarchal Western narrative of Cowboys and Indians in *Caprice*, Aritha van Herk has rejected all forms of the traditional narrative structure as a mould for shaping the Canadian identity in *No Fixed Address: An Amorous Journey*. While these authors use various techniques to allow for a redefinition of Canadian culture, it is primarily through the use of humour that Canadian writers are able to establish a community among their audience—a united front against the imposition of cultural 'history'.

Thomas King, in particular, engages with multiple forms of literary humour such as heavy sarcasm, and rather intense self-depreciation in order to define his sense of Canadian culture. King's The Truth About Stories: A Native Narrative actively rejects stereotypes of culture, specifically European and American romanticism of the "traditional Indian", as it applies to Canada. Written in the way a story is orated, The Truth About Stories refuses to conform to the traditional structure of literature: King uses story-like tales to raise issues of spirituality and identity that, while told with an intellectual voice, retain a level of colloquial language that is easily accessible to everyone. While King uses the oral tradition to emphasize his own Native culture, like virtually everything else in each of his novels, the oral narrative acts as a statement against preconceived notions of cultural identity. King's narrative technique relies heavily on a pseudo-soliloguy to relay information rather than resorting exclusively to structures of the written word: by "'orally' pointing out errors in the written stories" (Bailey 43), King has provided his marginal voice with greater authority; "the oral narrative strand pokes fun at what becomes the inflexibility of written texts and the superiority of the...oral story-telling technique" (43). Within The Truth About Stories, the oral text becomes the "vehicle through which reality is accurately represented" (Bailey 44).

Orality is closely tied to notions of the vernacular, as an experience is better explained through word of mouth. Speech adds a level of tone that the written word often has trouble conveying. For this reason *The Truth About Stories* is a highly successful interdisciplinary project. Originally published as a CBC Massey Lecture, *The Truth About Stories* was an oral production distributed to the public via the radio and internet. It is both the "territory of Native oral literature. And it is the territory of contemporary Native written literature" (King 114), a merging of both creative and critical writing in order to connect to the most significant number of people.

Written stories often have trouble being entirely memorable; Robert Kroetsch attributes this problem to the very fact that written stories are written: "we silence words by writing them down"(34), removing their ability to say anything substantial. Regardless of any changes an oral story may go through, the essence and message remain the same. A good story will not be forgotten, and it will be repeated by those who not only learned from it, but also by those who enjoyed hearing it. The conversational tone of King's oral form is used as a formative element in the construction of meaning, allowing readers to come away from *The Truth About Stories* feeling as though they have had a genuine human connection.

This human connection makes King's orality an efficient promotion of vernacular culture. The vernacular culture, as outlined by Clarke Mackey in his "Vernacular Manifesto," allows for a human collaboration, for the growth and experience of a home-oriented culture through actively participating within a community: by telling his readers his stories, rather than allowing them solely to read the stories on their own, King enables an active participation in the "conviviality, hospitality, and imagination" (246) represented within his stories and therefore has started to create his own community through a shared experience.

While exhibiting similar experiences and issues is entirely necessary in the establishment of a strong community, trusting the author is a primary concern, especially if the author is rejecting your knowledge of existing cultures and denouncing that knowledge as stereotype. King (like a great many Canadian writers), must be able to relieve the tensions surrounding his issues, while building rapport with his readers. The most effective way for King to do this is exactly the method he employs: self-deprecation. Human beings are more inclined to trust other humans that make fun of themselves, whether it be out of pity for the paltry existence described by the author or out of an admiration for the author's confidence. Either way, King's multiple jokes about his Native culture work not to offend his readers, but to make his culture more accessible. By making constant references to the Indian we know, or the Indian we think we know, as "Shadow Indians. Grey Indians. Not really Indians at all" (King 140) that regain status from a government that had historically tried to breed them out, King reinforces the instability of an assigned cultural identity while allowing the reader to laugh at the shadowy dominance of cultural metanarratives.

King appeals to a large variety of readers, particularly but not strictly Canadian readers, by making his stories universal— thereby are expanding his community. A concern for cultural identity is engrained within The Truth About Stories. Culture is expected to be a combination of inherited ideas, values, knowledge, and beliefs which characterize a shared society— it is not the notion that ideas, values, knowledge, and beliefs have the ability to define a culture that is the issue, instead the problems arise from the suggestion that these features are inherited. For King and many other Canadian authors, the problem with finding a Canadian identity is rooted here: if our shared society is inherited it is difficult to define it for ourselves. Therein lies a dominant dilemma: where there has been an excessive amount of concern for a definition of cultural identity it is, as Robert Kroetsch suggests, perhaps not the "task of the Canadian writer to give names to [their] experiences, to be the namer... on the contrary, it is [their] task to un-name" (58). Canada is calling for a fresh identity because she has spent far too much time in the shadows of Europe, and the United States, being grouped as a British colony, or as an obedient neighbour to America. As such,

in recent years the tension between this appearance of being just like someone else and the demands of authenticity has become intolerable— both to individuals and to the society. In recent Canadian fiction the major writers resolve the paradox— the painful tension between appearance and authenticity— by the radical process of demythology zing the systems that threaten to define them. Or, more comprehensively, they uninvent the world (58).

The Truth About Stories subscribes to this re-inventing of a Canadian identity by "undermin[ing] the authoritative narratives by raising questions about their primacy" (Andrews 69). One particular story enlightens King's readers as to why the image of the "traditional Indian" is particularly dominant in the world's mindset: in the early twentieth century, a British photographer by the name of Edward Sheriff Curtis set out to document the image of the North American Indian before it vanished, ending up with more than forty-thousand negatives (King 32). Some twenty-two hundred images were published and sold to the intrigued public back in Britain and on other continents. Fortythousand images! Twenty-two hundred prints! And the images were taken from across North America, so the amount of primary material available to define the culture was substantial. The world was able to develop a cultural image for the North American Indian, an image that remains the dominant idea of what an "Indian" looks like. However, King denounces Curtis' work as a viable source to base a cultural identity on, as Curtis' work is based on deception. In order to ensure a proper portrayal of the "dying Indian" Curtis "took along boxes of 'Indian' paraphernalia- wigs, blankets, painted backdrops, clothing- in case he ran into Indians who did not look as the Indian was supposed to look" (34). King rejects the presumed supremacy of the cultural definitions put in place by those outside of Canada and in so doing "induces cultural resistance to the dominance of nation" (Andrews 609) and prevents the "assimilation of Native tribal customs and traditions [such as orality] into a discourse of Eurocentric nationhood" (Andrews 601).

The sarcasm and aloof tone of King's orality allow the audience to digest this inauthentic attribution of cultural identity without becoming drastically offended. By making his audience laugh, King has not only made cultural 'statistics' blatantly inauthentic, but has also played upon the sense of community established among his readers. Although King applies the dishonesty of cultural fabrication in terms of a primarily Native experience, the personal oral story-like style lends itself well to the human experience. King uses a kind of metafiction— "which is, in some dominant and constituitive way, self-referential and autopresentational" (Hutcheon 228)— that represents something beyond a post-colonial Canadian need to reclaim the past (Eagleton 15) and is instead a social, historical, and ideological discourse that is a "discourse as en[u]nciation" (Hutcheon 236), allowing the "reader's realization of their equally essential discursive identity" (237).

The Truth About Stories makes a persuasive argument to suggest that there is little truth to "history," and that there is less cultural identity in a national textbook than there is hidden within an everyday conversation between community members. King, along with Kroetsch and many other Canadian authors, suggests, most convincingly, that seeking a reiteration of factual basis is the most effective way to attempt a new recipe for cultural vernacular— that working with the ingredients is far more rewarding than the same old stew. Rather than following the assumed story of Canadian culture, it is possible that changing our stories changes our world; vary the way in which you use the ingredients and you have a veritable record of recipes. For Thomas King, for Canadians, and arguably for humanity, there is no set definition of culture; Canadian culture changes from person to person, a vernacular individuality that each person can relate to: stories provoke an intimate knowledge of each other's culture as "the truth about stories is that that's all we are" (King 2).

References

- Andrews, Jennifer and Priscilla L. Watson. "Rethinking Canadian and American Nationality: Indigeneity and the 49th Parallel in Thomas King". *American Literary History*. 18.3 (2006). 600-617. Web. 22 Nov. 2011. << http://alh.oxfordjournals.org/>>>
- Bailey, Sharon. "The Arbitrary Nature of the Story: Poking Fun at the Oral and Written Authority in Thomas King's 'Green Grass, Running Water'. World Literature Today. 73.1 (1999): 43-52. Web. 22 Nov. 2011. << http://www.jstor.org/stable/40154474>>
- Cohen, Andrew. The Unfinished Canadian: The People We Are. Toronto: McClelland & Stewart, 2007.
- Eagleton, Terry. Literary Theory: An Introduction. Oxford: Basil Blackwell, 1983.
- Hutcheon, Linda. "Canadian Historiographic Metafiction". Essays on Canadian Writing. PMLA, 1984-1985. Web. 4 Nov. 2011.
 - <<http://www.web.ebscohost.com.ezproxy.tru.ca>>
- King, Thomas. *The Truth About Stories: A Native Narrative*. Toronto: House of Anansi Press, 2003.
- Kroetsch, Robert. Seed Catalogue. Calary: Red Deer Press, 2005. "Unhiding the Hidden". The Lovely Treachery of Words: Essays Selected Old and New. Oxford: Oxford University Press, 1989. 58-63.
- Mackey, Clarke. "A Vernacular Manifesto". *Random Acts of Culture: Reclaiming Art and Community in the 21st Century.* Between the Lines, 2010. 238-246.

Community Economic Development Report for Duncan: Strategies for Seniors, First Nations Partnerships, and the Creative Economy

Bonnie Klohn

Interdisciplinary Studies

Supervisor: Dr. Laura Lamb

Abstract

The City of Duncan is facing several major problems in terms of long-term municipal sustainability and prosperity, including a declining forestry sector, an aging population, and the decline of businesses in the downtown core. Duncan already has a well-established network of basic community economic development networks, so the suggestions in this report are meant to address weaknesses and threats to Duncan's economy with ideas based on Duncan's strengths and opportunities that have not been previously tried.

The overarching strategy used is based on business development (Blakely and Bradshaw, 2002). There are three main short term goals set out in this plan. First, attracting seniors to boost economic activities; second, increasing partnerships with neighbouring First Nations and finally supporting business development services already in place in the area. In the long term there are four main goals: (1) maintaining the "downtown core" status within the Cowichan Valley, (2) increasing the creative economy in Duncan, (3) attracting skilled immigrants and, (4) supporting Economic Development Cowichan's efforts to attract the film industry to Duncan and the Cowichan Valley.

This report is meant to give a background and context to some of the strategies Duncan is already undertaking, as well as new innovative strategies that are emerging in community economic development and planning literature. One of the primary contributions this report makes to the existing information on economic development in Duncan is the focus on ameliorating and using the creative economy in the long term to retain young people in the city; a new field of study in planning literature, particularly pertaining to cities the size of Duncan. In addition, an overt examination of the important role senior's care will provide economically in the city is a significant contribution to the existing concepts on planning for economic development in Duncan. Finally, a look at how Duncan can take advantage of the principles behind some recent research on First Nations economic development opportunities might benefit all communities in the area as well. A feasibility study would be required to prioritize and assess the costs and benefits of each of the strategies and goals suggested in this report.

Introduction

Duncan's economy has been traditionally reliant on the forestry sector in the Cowichan Valley. Recently, the forestry sector has slowed, resulting in fewer jobs in the nearby pulp and papers industry. Economic shifts like this can represent an opportunity to innovate and create a new identity that better prepares Duncan for the changes that are taking place on a global scale. There are many areas in which Duncan is doing very well in terms of development. Their "solar community" policies (Solar BC, 2008), walkable landscape (Ireland, 2012) and the participation in the community (Canadian Council on Learning, 2012) are already strong aspects of Duncan that don't need changing. In this paper I will discuss how Duncan can encourage business development in innovative ways that haven't already been pursued by the city, and offer some context in terms of literature on development strategies. This plan highlights, among other things, a healthy and supportive place for seniors to retire in, partnerships and inclusivity to the neighbouring First Nations population and a business development strategy based on creativity that will continue to attract young people and families in the long term.

Methodology

This report is meant to apply concepts in planning literature to Duncan, B.C. The four strategies outlined in Blakely and Bradshaw's 2002 book *Planning Local Economic Development*, (locality development, business development, human resources development and community based development) are used as a starting point for the analysis of appropriate and potentially effective economic development activities. Research on Duncan was completed using the Statistics Canada Community Profile and other available Statistics Canada data. In addition, a web and print search was completed to access information about Duncan, the Cowichan Valley area and the First Nations communities in the region. Furthermore, an interview was conducted with Tim Ireland, the Chief Executive Administrator of Duncan. A literature review of theories, concepts and case studies in development planning was then conducted, based on Duncan's identified strengths and weakenesses in economic development in the short and long term.

Community Economic Development Strategies

Blakely and Bradshaw (2002) suggest four overarching strategies to consider in local economic development: locality development, business development, human resources development and community based development. While

elements of all four strategies will be used in the strategic plan for Duncan, the primary focus of economic development will be business development. The changes in Duncan reflect Blakely and Bradshaw's assessment that "business development is the most important component of local economic planning because the attraction, creation or retention of business activities is the best way to build or maintain a healthy local economy" (p. 217). There are several reasons that this is particularly true for Duncan. The population in Duncan is growing significantly in age groups over 75 (Statistics Canada, 2006). This will be its main challenge in the long term but perhaps its main opportunity in the near future. As the baby boomers eventually stop moving to Duncan from the surrounding areas, Duncan will need to have an age demographic that is much more diversified than it is now in order to avoid serious population decline. In addition, the numerous resident retirees result in a participation rate that is just above 50% in Duncan, which is much lower than the provincial average (ibid). Young people are needed to ensure that current Duncan businesses stay. The best way to attract and retain young people is by offering viable career options.

Blakely and Bradshaw's other strategies will come into play, especially community development in the arts as a form of new business activities. Human resource development is suggested only for a few specific areas. Locality development is less important in Duncan as it is one of the smallest municipalities in BC, is already very walkable and contains the only truly distinct downtown center in the Cowichan Valley. It holds much more locality attraction than the surround area already. Duncan's needs revolve primarily around attracting new business.

The Business Development Plan

This plan consists of both long term and short-term strategies. The long-term suggestions such as fostering the creative industry and attracting skilled immigrants to Duncan take longer to properly complete, perhaps upwards of 15 years, while short-term strategies are meant to be achievable in the 1-5 year timespan.

Short-term Strategies

Seniors as an economic advantage

As mentioned above, in the short term seniors can play an important role in bolstering the local economy. The influx of seniors due to the baby boomer generation can provide high quality jobs in health care, and, as the need for care increases as seniors in the Cowichan Valley age, Duncan is the logical spot for families in the area to seek out higher level care for their parents or grandparents.

Attract Retirees: Marketing Strategies

Attracting retirees to communities has been the focus of many development strategies for small cities, particularly in the southern Unites States. One strategy is to reach out to seniors through traditional marketing methods. Billboards, mail outs and newspaper ads promoting geographic qualities seniors look for, such as temperate climates, availability of health services and easy access to transportation, can help cities draw retirees (Reeder, Hopper, & Thompson, 1994). On the other hand, some cities have focused on building amenities first in order to attract seniors. Planned seniors villages offer a "build it and they will come" strategy to cities that are hoping to reap the economic benefits of the retirement age demographic (ibid). Duncan has little room to build an entire seniors village, so making sure it is well known in the Cowichan Valley and the rest of Vancouver island that Duncan has all the amenities necessary for seniors (including a temperate climate and walkable city) would be the most helpful tool for attracting seniors.

Communication with Seniors

In order to properly care for seniors, and therefore to attract them to come to Duncan, the city might want to aid in helping seniors connect with services. Seniors often have a poor awareness of the services that may be able to help with day-to-day tasks, with rent subsidization, other financial support and transportation, making the transition from their previous lifestyle difficult (Ryser & Halseth, 2011). Some techniques that Duncan can use to overcome this problem include: supporting the collation of important information in the form of a newsletter, newspaper or information packages for seniors; providing information to seniors via the professionals that already provide home care services, such as book delivery services through the library; sending letters to seniors in the mail; two way dialogues such as workshops and educational meetings; addressing limited resources of not-for-profits that are trying to provide services by providing them with free advertising, or supporting pooling resources with other not-for-profits for mail-outs; provide resource information at natural gathering places like doctors offices, community centers and the library; and finally, websites can be a valuable resource for many seniors, particularly if they are accompanied with some basic training on computer use (ibid).

Training Programs for Care Aids

Duncan's two community colleges already offer programs for residential home care attendants, and practical nursing (Linx BC, 2009). However, it may help to provide further assurance seniors will receive proper care if there were an ample number of trained professionals in this field. Duncan may want to aid the colleges in promoting these programs either by providing in-kind advertising space or scholarships for students that plan to enter into these careers and stay in the area.

First Nations

For a city like Duncan whose populations are rapidly increasing in age, the First Nations reserves nearby represents a much needed group of people in a family age demographics. The average age of the First Nations population is much younger than the population in Duncan (Jack, No Date), and the potential for partnerships in economic development with the city may be an opportunity to explore mutually beneficial ventures.

Partnerships with Khowutzun Development Corporation

The Cowichan Valley First Nation has an Aboriginal Financial Organization called the Khowutzun Development Corporation (KDC). They have been very successful in helping aboriginal enterprise succeed, and helping to create jobs for Cowichan Frist Nations. For example, KDC won a Council for the Advancement of Native Development Officers (CANDO) aboriginal economic development recognition award for their role in support the start up of an aboriginal company Khowutzun Mustimuhw Contractors, who install natural gas pipeline in residential areas on Vancouver Island (Classen, 2000). The KDC also helps aboriginal people obtain employment in the forestry industry, owns a First Nations Village where visitors can come and learn about the aboriginal people in the area, and supports other first nations businesses such as a kitchen and bath center (Khowutzun Development Corporation, 2007).

This type of economic activity, that helps people close to Duncan, is very beneficial for maintaining populations in the city over the long term. Building partnerships with the Cowichan Indian Band may help Duncan to be able to market to businesses that need a bigger workforce than Duncan has to offer itself. To this end, Duncan might want to train a liaison person to work with the KDC. Organizations like the National Aboriginal Capital Corporations Association (NACCA), Aboriginal Financial Officers Association of Canada (AFOA), and CANDO all offer classes that can accessed either online or through some post-secondary institutions, that help people working in the field the intricacies of First Nations Finance (Oppenheimer, O'Connell, & Weir, 2012). Although Duncan wouldn't have access to the same fund as aboriginal organizations, it would benefit the city to partner in attracting firms.

First Nations Education

Currently Vancouver Island University (VIU) offers the first two years of a four-year degree in Native Indian Teacher Education (Vancouver Island University Cowichan, 2012). Given the much-needed potential work force the aboriginal youth near Duncan represent, teaching and education is extremely important. Lobbying VIU to offer this degree as their first full four-year degree on the Cowichan Campus might help to greatly reduce the barriers that exist for those considering the program.

Long Term Strategies

In the long term, Duncan will have to rely on more than the influx of aging seniors and the neighboring First Nations groups. Duncan needs to attract citizens that will continue to contribute to its tax base and provide an important active workforce. There are several ways to foster a business climate that will allow for opportunities that will attract people to Duncan and retain current residents. Duncan's location, directly between Victoria and Nanaimo, is an advantageous factor for business development such as this (Reimer, 2006). However, public policy needs to reflect the modern changing economic context and focus on making Duncan a city that can survive on more than forestry alone.

Business Climate Tools

An article by Chatman et al. (2008) showed factors that increased the perception of entrepreneurial climate for entrepreneurs in the area included fair treatment within communities, the a higher level of local patronage, the availability fo business networks and high speed internet. Start-up and venture financing programs like Community Futures, which serves as a Community Development Finance Instition (CDFI) in the Duncan region might help to attract and retain business owners in the city (Blakely & Bradshaw, 2002). Economic Development Cowichan might want to do more mentorship programming and training for small business management to help prevent the failure of new businesses that is so commonly due to improper management (ibid).

Duncan as a Downtown Core for the Cowichan Valley

Duncan is the primary downtown core for the Cowichan Valley, a region that is home to over 80,000 people. Maintaining this role will be extremely important for Duncan to prosper, however, there are already indicators that Duncan currently doesn't allocate enough resources to its downtown core. The first indicator is the location quotient for business services and finance and real estate, which are 0.63 and 0.62 respectively (Statistics Canada, 2006). This indicates that Duncan actually has less of the services normally found in a downtown core than the rest of BC. Business services in Duncan fell 12.8% compared to the total economy in BC, and fell 14.3% compared to the same industry in BC. This shows that as a business service center Duncan is loosing its comparative advantage. The real estate and finance industry show very similar trends compared to BC. Retail trade and health care and social service locations quotients are quite healthy, which is positive, but regardless, it would be in the best interest of the municipality to try to bolster its downtown business activities.

Sense of place is very important in a downtown core. Robertson (2000) discusses techniques for increasing character of a downtown core which will in turn attract businesses and new residents to the city. Downtowns must have a distinctly different from the surrounding area, show the heritage of a city, and be extremely multifunctional (shopping, eating, workplaces, diverse service and goods businesses). Any downtown core should be walkable, and have a strong sense of human activity, and areas to linger such as coffee shops, sitting spaces, music and games like chess available for people to take advantage of. Blakely and Bradshaw (2002) talk about this type of locality development as a means to attract business, but for Duncan, it is a strategy to maintain the current businesses in the area, as well as attract new ones.

Duncan's Creative Economy

Many cities the size of Duncan have to reinvent themselves in particularly creative ways to create a sense of place. Bell and Jayne (2006) call placing making practices such as Duncan's totem pole collection Unique Selling Points (USP). Duncan is obviously using this USP to make a name for itself, however, there are many things Duncan can do to go above and beyond in creating a unique culture that fosters businesses that are unique, creative and beneficial for the whole community.

Fairly recently, the notion of the "creative economy" has emerged in the city and community planning literature. In addition "there has been growing recognition of the role that the arts and artists play in economic and community development" (Grodach, 2010: 74). The development of the arts sector provides essential skilled labour, as well as attracts more highly educated and skilled people to settle in the area (Florida, 2003; Grodach, 2010). A creative city attracts a core of musicians, engineers, cultural sectors workers or highly trained problem solvers, which in turn fosters businesses with local linkages as well as the capacity to access far reaching markets. Florida attributes success in creativity to the three T's: tolerance, technology, and talent. This theory has been shown to be quite accurate for correlations with actual economic growth (ibid.).

Contrary to Florida's prescription for success, between 2001 and 2006 Duncan saw arts, culture and recreation drop 70% (Statistics Canada, 2006). Developing a healthy arts sector has both the direct benefit of providing jobs and revenue for local citizens, as well as the indirect benefit of increasing the aesthetic value of the municipality land itself (Phillips, 2004; Florida, 2003; Grodach, 2010). There are some specific tools that municipalities can use to foster a more robust arts center such as providing arts spaces, grants for art cooperatives and bringing together arts and tourism through branding initiatives (see Phillips, 2004; Grodach, 2010).

Attracting Immigrants for Population and Cultural Diversification

An influx of immigrants can be extremely beneficial for a small city like Duncan for a few reasons. First, as the population ages, immigrants can provide an inflow of young people that help boost the workforce. In particular, skilled immigrants can be a major attraction to businesses considering locating in the area. Secondly, cultural diversity increases the attractiveness of a city to other educated skilled workers. Culture and diversity are a big part of what attracts young educated people to cities such as Vancouver, Toronto and Montreal (Florida, 2003; also see Walton-Roberts, 2005). Although small cities function differently than these large Canadian metropolises, slowly diversifying the age and cultural demographic of Duncan over a 10 to 15 year period will have many long-term benefits. The city of Duncan should consider partnering with organization that might be able to provide funding for new Canadians in the area or advocating for more government funding for immigrant service in the area.

Cowichan Valley Film Industry

Cultivating a creative industry not only makes sense in terms of attracting business, it fits in with Economic Development Cowichan's current programs that strongly encourage the film industry in the area. Artists and film makers in a creative city, if managed correctly, have the potential to draw both workers *and* tourist from BC and the rest of Canada. Duncan is very well suited for this because of its proximity to Vancouver, a major North American film locale, and to other tourist destinations on Vancouver Island (such as Victoria and Tofino). Duncan will be able to attract visitors while they are already in the area. Blakely and Bradshaw (2002) warn that tourism as a tool for economic development is not appropriate in all cities, however, because of its geographic location and temperate climate it would greatly benefit Duncan to support Economic Development Cowichan's efforts in increasing film and tourism in the area.

Conclusion

Duncan is fortunate because many of the business development strategies that Blakely and Bradshaw suggest are already covered either by the municipality, Economic Development Cowichan or the development organizations it supports such as Community Futures. In addition, Duncan is doing well in terms of sustainability planning, and most social programs. However, given the decline in the forestry sector, the indicators in the socio-economic overview suggesting that Duncan is losing its strength as a downtown core for businesses in the Cowichan Valley, the aging population, and the loss of employment in the arts sector in Duncan, this report will hopefully emphasize strategies that are new to Duncan as a development tactics. Ultimately, in the long term Duncan will need to think outside the box to survive the loss that the end of the baby boomer generation will represent. In fifteen years time, the cities that are thriving will be the ones that have managed to diversify away from the tradition economies in small towns, and carved a unique niche for themselves. Using seniors and First Nations partnerships in the short term to stabalize the loss of income from the forestry sector, and capatalizing on Duncan's geography in a populous yet spread out region in the long term will put the city in a good position to reinvent itself as a creative, cultural, tourist friendly community.

Bibliography

- Bell, D. and Jayne, M. (2006) "Conceptualizing small cities". In Bell, D. and Jayne, M. editors: Small Cities: Urban Experience Beyond the Metropolis. New York, Questioning the Cities Series, Routledge.
- Blakely, E., & Bradshaw, T. (2002). Planning Local Economic Development: Theory and Practice (3rd Edition ed.). Thousand Oaks, US: SAGE publications.
- Canadian Council on Learning. (2010). 2012 CLI Profile: Duncan BC. Composite Learning Index. Canadian Council on Learning. Retrieved February 12, 2012 from: http://www.cli-ica.ca/en.aspx
- Chatman, D., Altman, I., & Johnson, T. (2008). Community Entrepreneurial Climate: An Analysis of Smal Business Owners Perspectives. *Journal of Rural and Community Development*, 3(1), 60-77.
- Classen, A. (2000). CANDO Aboriginal Economic Development Recognition Awards. Journal of Aborginial Economic Development, 1(2), pp. 14-27.
- Economic Development Cowichan. (No Date). *Economic Data*. Retrieved March 16, 2012, from http://www.cvrd.bc.ca/index.aspx?nid=588
- Economic Development Cowichan. (No Date). Cowichan Region-Things Look Better From Here. Retrieved March 16, 2012a, from Business Expansion: http://bc-cowichanvalley.civicplus.com/DocumentView.aspx?DID=912
- Florida, R. (2003). Cities and the Creative Class. City and Community, 2(1), 3-19.
- Grodach, C. (2010). Art Spaces in Community and Economic Development: Connections to Neighborhoods, Artists, and the Cultural Economy. *Journal of Planning Education and Research*, 31(1), 74-85.
- Ireland, T. (2012, February 8). (B. Klohn, Interviewer) Duncan, BC, Canada.
- Jack, J. (No date). *Cowichan Tribes*. Retrieved February 12, 2012, from http://www.joejack.com/cowichantribes.html
- Khowutzun Development Corporation. (2007). Visit our company websites. Retrieved March 14, 2012, from Khowutzun Development Corporation: http://www.khowutzun.com/
- Lachman, K. (No Date). Business Facts. (E. D. Cowichan, Producer) Retrieved March 16, 2012, from The Cowichan on Vancouver Island- Things Look Better From Here : http://bc-cowichanvalley.civicplus.com/DocumentView.aspx?DID=936
- Lamb, L. (2008). Opportunities and Challenges: What does the New Economy have to Offer Aborginial Economic Development? *The Journal of Aboriginal Economic Development*, 6(1), 44-66.
- Linx BC. (2009). Site Selection Guide. Cowichan Valley Regional District. Duncan, BC: Economic Development Cowichan. Retrieved February 13, 2012 from: http://www.cvrd.bc.ca/DocumentView.aspx?DID=1362
- Oppenheimer, R., O'Connell, T., & Weir, W. (2012). Training Opportunities in Aboriginal Business, Community, and Economic Development Being Offered Through Aborginial Organizations. *The Journal of Aboriginal Economic Development*, 7(1), 19-25.
- Phillips, R. (2004, April). Artful business: Using the arts for community economic developmen. *Community Development Journal*, 39 (2), 112-122.

- Rausch, A. (2009). Capitalizing on Creativity in Rural Areas: National and Local Branding in Japan. *Journal of Rural and Community Development*, 4(2), 65-79.
- Reeder, R., Hopper, R., & Thompson, C. (1994). Rural Retiree Attraction: Recent Trends and Strategies. In R. Wolensky, & E. Miller (Ed.), *The Small City and Regional Community*. *11*, pp. 145-152. University of Wisconsin-Stevens Point, Center for the Small City.
- Reimer, B. (2006). The Rural Context of Community Development in Canada. *Journal of Rural and Community Development*, 1(2), 155-175.
- Roberton, K. (2000). A strong downtown sense of place. In R. Shaffer, & W. R, *The Small City and Regional Community* (Vol. 14, pp. 389-395). Center for Community Economic Development and University of Wisconsin-Extention, Center for the Small City.
- Ryser, L., & Halseth, G. (2011). Communication Mechanism for Delivering Information to Seniors in a Changing Small Town Context. *Journal of Rural and Community Development*, 6(1), 49-69.
- Statistics Canada. (2006). 2006 Community Profiles- Duncan. Census 2006. Ottawa: Statistics Canada. Retrieved February 13, 2012 from: http://www12.statcan.ca/census-recensement/2006/dp-pd/prof/92591/details/page. cfm?Lang=E&Geo1=CSD&Code1=5919012&Geo2=PR&Code2=59&Data=Count&Searc hText=Duncan&SearchType=Begins&SearchPR=01&B1=All&Custom=
- Solar BC. (2008). *Duncan: Involved and Inspired*. Retrieved February 12, 2012, from Join the Solar Revolution: http://www.solarbc.ca/solar-communities/duncan
- TFC Consulting Ltd. (2009, March 27). The Cowichan Valley Clean Technology Sector: Opportunities for Development. 1. Cowichan Bay, BC, Canada. Retrieved February 12 2012 from: http://www.cvrd.bc.ca/DocumentView.aspx?DID=1325
- Vancouver Island University Cowichan. (2012). *Programs and Courses*. Retrieved February 12, 2012, from Cowichan Campus: http://www.cc.viu.ca/progserv/programs.htm
- Walton-Roberts, M. (2005) "Regional immigration and dispersal: lessons from small- and medium-sized urban centres in British Columbia." *Canadian Ethnic Studies / Études ethniques au Canada*, 37 (3) 12-34.

Value of Residential Building Permits for Single Family Dwellings in Canada: What does the future hold?

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Abstract

The purpose of this paper is to develop a model that will produce an accurate and reliable forecast of the value of residential building permits for single family dwellings in Canada. In light of the most recent Canadian recession, it is more important to examine the dynamics between many variables on the economy that could indicate economic downturn. Amongst many variables that can be considered in determining the state of the economy, the value of residential building permits for single family dwellings is one of the most significant indicators. These values vary as a result of fluctuations in the number of permits, mortgage interest rates, inflationary and deflationary pressures, as well as contractions and expansions of the economy. A slump in the housing market, as seen in late 2008 economic contraction, can be a strong indicator that the economy is entering or already in a recession. Thus, accurate forecasts of the value of building permits in Canada could lead to a better understanding of the state of the economy and be helpful in anticipating economic expansions and contractions. This research utilized historical quarterly data from first quarter of 1993 to the first quarter of 2011. The combination of the estimated multiple regression and Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model produced the most improved and reliable forecasts for the value of residential building permits of single family dwellings in Canada.

Introduction

In light of the most recent recession in Canada, it is important to understand the general effects of many variables on the economy that could indicate downturn. There are many variables in the economy that can be considered useful in determining the state of the economy. The change in the value of residential building permits for single family dwellings is the results of changes in the number of permits, mortgage interest rates, inflationary and deflationary pressures, as well as contractions and expansions in the growth of the economy. A slump in the housing market, as was seen in the recent economic contraction can be a strong indicator that the economy is entering or already in a recession. Therefore, the successful forecasting of the permit values in Canada could lead to understanding how these values change over time, what impacts these values and thus lead to the ability to anticipate economic expansions and contractions.

The purpose of this paper is to develop a model that will produce an accurate and reliable forecast of the value of residential building permits for single family dwellings in Canada. The topics of this paper have been broken down as follows. First, a brief introduction to the data set and a short literature review on the subject area. Second, will be an examination of some forecasting techniques which include multiple regression, time-series decomposition and Box-Jenkins. Third, these techniques will be combined to determine if the forecasts can be improved by combining these models. Finally, the model that provided the most reliable results was chosen to forecast the permit values for the next twelve quarters.

Data Set

This research utilizes historical quarterly data from first quarter of 1993 to the first quarter of 2011. This data was obtained from the Bank of Canada and Statistics Canada website. The following variables were collected from Statistics Canada: average value of residential building permits for single family dwellings (026-0001), average residential mortgage lending rate (176-0043), growth rate of gross domestic product at market prices (380-0015), unemployment rates for age 15 and over (282-0087), and population (051-0005). The core inflation rate was attained from the Bank of Canada.

Literature Review

There has been very little research in developing a forecast model to predict the value of residential building permits. There has, however, been research in the field of housing starts and housing prices.

One such study which was concerned with developing an econometric model of house prices in Hong Kong. These researchers found that housing prices are sensitive to population growth which "puts direct pressure on the demand for housing services" and interest rates which when they are declining leads to appreciation of the price of houses "making rental housing relatively less expensive". Another factor this study determined had an impact on the house prices was inflation. When inflation rises it leads to an increase in home ownership rates "because of the tax deductibility of interest expense compared to rental costs" leading to higher demand for houses. The inflation also increases the prices of these homes which attracts investors as "residential property was viewed as favorable investments to hedge against inflation". (Tse, Ho, & Ganesan, 1996)

In another study, that looked at forecasting the growth of construction markets where the factors considered were the Gross Domestic Product, interest rates, population growth and unemployment rate. It was noted that GDP Growth leads to construction output showing "a causal link between the economy and the construction sector". The interest rates influence the lending costs and thus a higher interest rate implies higher costs to clients, contractors and buyers and thus has negative effects on the construction market. In addition, the unemployment rate signals whether the economy is healthy or not which can have a significant impact on the construction market. The population also has a strong influence on the market because it "could generate a demand for new infrastructure and construction facilities to accommodate" the change in demographics and population migration. (Fan, Thomas, & Wong, 2011)

In considering these factors and their relationship to housing prices, it is safe to assume that these factors also impact the value of residential building permits of the said houses since the number of housing starts and the value of the permits for those starts relate to the price of the houses.

Methodology

Multiple Regression

The first model utilized is multiple regression which examines the relationship between a dependent variable and a number of independent variables. As the purpose of this research is to find a model that will accurately forecast the value of residential building permits of single family dwellings, this will be considered the dependent variable. A sign of economic downturn in the recent recession was a slump in the Canadian housing market that led to a decrease in the number and value of residential building permits in particular those of single family dwellings. As such, this is considered an important indicator of economic conditions in Canada.

The permit value represents the value of a single family dwelling, thus as mortgage interest rates rise the cost of owning a home increases. Larger homes naturally have higher permit values and thus if the cost of owning a home rises, the number and size of homes would fall and thus the average value of permits would fall for that period. In addition, there may be some willing to take out a permit to build a smaller home due to the increased mortgage rates and thus the values of permits would fall.

As general prices increase in the economy, the cost of building materials would likely follow and this increase in cost would tend to raise the value

of the building permits. The best indicator of this price increase is the core inflation rate, as it represents the consumer price index less the most volatile components, one of which is the mortgage interest rates, thus by choosing the core inflation rather than the CPI inflation rate one can avoid correlation between this variable and the mortgage interest variable. In other words, one can observe the separate impact that these two variables have on the permit values.

In terms of the impact the state of the economy has on the permit values, I choose to incorporate both the growth rate of gross domestic product and the total unemployment rate. As the economy experiences growth the values of the permits would increase simply due to expansion. With regards to the unemployment rate, the general assumption would be that as the unemployment rate increases this would lead to a decrease in the permit values – one reason being the inability of those who were previously employed to build homes and thus as the number of permits decreases so would the value. Another reason, is the combined effect of an increase in unemployment and a decrease in the GDP growth rate which is often an indicator of a recessionary period in the economy. Thus, with these coinciding values would lead to an overall decrease in the values of permits.

The final variable used in this model was the population. Due to the rules of supply and demand, as the population increases there is increased demand for single family dwellings and this pushes up the cost of supplying homes, and thus increases the value of the permits needed to provide those homes.

A common problem with time-series data is heteroskedasticity which can lead to incorrectly interpretation of regression results. A widely used test for this problem is the White Test. The results of this test are shown in Appendix, Chart 1; which were obtained using Eviews 6 software. The p-value for the F-statistic was 0.0554, and thus when tested at the 95% confidence level results in the rejection of the null hypothesis. This means that if a simple multiple regression model were to be used, heteroskedasticity would exist. However, to prevent this from being an issue the multiple regression model used was one in which the logarithm of the dependent variable was taken.

L_VALUE=f(MIR,INF,GROWTH,POP,UNEMP) Where:

L_VALUE represents the logarithm of the value of residential building permits for single family dwellings

MIR represents the average residential mortgage lending rate

INF represents the core inflation rate

GROWTH represents the growth rate of Gross Domestic Product at market prices

POP represents the population

UNEMP represents the total unemployment rate

The results of this model were obtained from ForecastX software and are given in Table 1. The p-values conclude that all the variables are significant to the model when tested at the 95% confidence level. The coefficients are consistent with the assumptions outlined above, with mortgage lending rate and unemployment having a negative relationship with permit values and the inflation, GDP growth and population having a positive relationship with permit values. Although, in this table the population shows as a coefficient of 0.000, its actual value is 1.349E-7; the impact is quite small but is significant to the model. When the model is run without the population the adjusted R² falls. In the current model the adjusted R² is 82.07%, which demonstrates that 82.07% of the variation in permit values is explained by the variables in the model.

Audit Trail Coefficient Table (Multiple Regression Selected)				
Series Description	Coefficient	T-test	P-value	
L_VALUE	10.248	8.58	0.00	
MIR	-0.059	-1.92	0.06	
INF	0.139	2.48	0.02	
GROWTH	0.051	9.33	0.00	
POP	0.000	4.48	0.00	
UNEMP	-0.043	-2.20	0.03	
Accuracy Measures			Value	
Mean Absolute Percentage Error (MAPE)			1.00%	
R-Square			83.32%	
Adjusted R-Square			82.07%	
Root Mean Square Error			0.18	

Table 1: Summary of Log-Linear Regression Results for Permit Values

The forecasted values for the log-linear model are as follows:

Since this was a forecasted permit values were in the logarithm form, I performed an anti-log calculation to show the actual permit values forecasted by this model.

Forecasted Values			
	L_VALUE	VALUE	
Jun-2011	14.71	2456586	
Sep-2011	14.77	2609338	
Dec-2011	14.53	2051467	
Mar-2012	14.31	1640733	
Jun-2012	14.78	2619325	
Sep-2012	14.82	2724511	
Dec-2012	14.59	2175376	
Mar-2013	14.37	1741455	
Jun-2013	14.84	2782019	
Sep-2013	14.89	2933191	
Dec-2013	14.66	2317594	
Mar-2014	14.43	1855318	

Table2: Forecasted Permit Values

Time Series Decomposition

The second technique utilized in this paper, is the time series decomposition. Unlike multiple regression which has a dependent variable and several independent explanatory variables, time series decomposition uses only the variable one is attempting to forecast. It attempts to determine the patterns that exist in the historical data, then applies those patterns to the forecast. This type of model breaks the variable down into its component parts; that is, trend, cyclical, seasonal and irregular. Typically, irregular is assumed to be equal to one, as it is the most difficult to predict. In this case, the model is applied to the value of permits. When the permit values are plotted against time, there is an obvious pattern that exists in the data – see Figure 1. There are two patterns that appear to exist in this data series. The first is seasonality, which is identifiable due to the consistent increases and decreases occurring the same time each year. The second is trend, which can be seen as the data tends to move upward. The time series decomposition model will identify these patterns and attempt to produce a forecast the permit values twelve quarters into the future with these patterns.





The first thing the model does is remove the short-run fluctuations, that is, it calculates the seasonal indexes. In this case, these seasonal indexes were as follows: Quarter 1 = 0.77, Quarter 2 = 1.28, Quarter 3 = 1.10 and Quarter 4 = 0.85. This means that in the first quarter of each year the permit values are 23% below average, in the second quarter they are 28% above average, the third quarter values are 10% above average and the values are 15% below average in the fourth quarter.

The second thing the model does is determine the long-term trend within the data. Figure 2 shows the permit values, centered moving average and the centered moving average trend. As one can see from this figure, there is clearly a positive trend existing in the data which means the permit values increase through time. The reason for this trend is not covered in this type of model, however, as demonstrated in the previous multiple regression models this increase is likely due to inflation, growth in GDP, and increase in population. There may be other factors affecting this trend, but they will not be covered in this research.



Figure 2: Permit Values, and Centered Moving Average Trend

Figure 3: Cycle Factors for Permit Values


Once the seasonality and trend have been determined, the next thing the model looks for is the cyclical factors. See Figure 3 which shows a clear wavelike pattern. A cyclical factor of greater than one indicates that the deseasonalized values are above the long-term trend for that period, while the opposite is true when the cyclical factor is less than one. This is a difficult component to project into the future as the length and amplitude are generally inconsistent over time. However, this is a very important piece to economists as it can be an indicator of future economic conditions.

The results of this forecast technique are as follows. The mean absolute percentage error was 4.60%. The R² showed that was 97.49% of the variation in the model is explained by the trend, seasonal and cyclical factors shown; it is safe to assume that the remaining variation is coming from the irregular component. And the root mean square error is 86,490.19.

Box-Jenkins

The multiple regression models used exogenous factors to predict the value of permits; this model is called a causal model. However, there are many situations that these determinants are either unknown or not available and in these cases one can make use of another forecasting technique called autoregressive integrated moving average (ARIMA) and is found using the Box-Jenkins methodology. It looks at the historical pattern in the data and using the most recent observations will analyze errors in the forecast to adjust the time periods in the future. It essentially finds a model that results in the residuals that are left over being white noise or purely random numbers that are normally and independently distributed.

Accuracy Measures	Value
Mean Absolute Percentage Error (MAPE)	7.94%
R-Square	92.54%
Adjusted R-Square	92.33%
Root Mean Square Error	149,087.39
Method Statistics	Value
Method Statistics Method Selected	Value Box Jenkins
Method Statistics Method Selected Model Selected	Value Box Jenkins <u>ARIMA(</u> 2,0,0) * (0,1,1)
Method Statistics Method Selected Model Selected T-Test For Non Seasonal AR	Value Box Jenkins <u>ARIMA(2</u> ,0,0) * (0,1,1) 12.87
Method Statistics Method Selected Model Selected T-Test For Non Seasonal AR T-Test For Non Seasonal AR	Value Box Jenkins <u>ARIMA(</u> 2,0,0) * (0,1,1) 12.87 -3.65

Table3: Summary Results for Box Jenkins Forecast

Table 3 shows the results of this model. The ARIMA model that was chosen by the software was ARIMA(2,0,0)*(0,1,1) and is interpreted as follows. The first three numbers represent the non-seasonal portion of the data, which required 2 lag periods of the autoregressive term, no differencing and no lag in the moving average term. The second set of three numbers represents the seasonal aspect of the data. There were no lags in the seasonal level of the autoregressive term, one level of seasonal differencing and one lag in the seasonal level of the moving average term.

The adjusted R^2 for this model is 92.33%, which means that the majority of the variation in permit values is explained in this technique. The mean absolute percentage error is 7.94%, which is higher than that for the time-series decomposition model. The root mean square is also higher than that for decomposition, at 149,087.39 compared to 86,490.19. This demonstrates that the time series decomposition appears to be the better model in this case.

Combination of Forecasts

The general procedure for choosing the best forecast of the same value is to take the forecast technique that results in lower root mean square error. Typically the models with higher errors are discarded. However, this is does not seem like a rational method because each technique makes use of valuable information and relationships that may be lost when a model is discarded. Therefore, it is a common practice to use a technique that combines different forecasts of the same value in order to make use of the information and relationships from each forecast in order to produce a more accurate model with reduced errors. Thus, the combined model in theory should have more predictive power than the individual forecasts. Four different combination models will be performed in this paper: multiple regression with time series decomposition, multiple regression with Box-Jenkins, time series decomposition with Box-Jenkins, and one that combines all three techniques.

Since the multiple regression model chosen in this research was a loglinear model, thus the forecasted values are the logarithm of the permit values. In order to combine this regression with the other two models the same dependent variable must be used, that is the value of permits; therefore, the anti-logarithm must be taken from the regression results.

The results of the combined forecasts are shown in Table 4. The standard for choosing the best model is the error minimization criterion; that is, the model that has the lowest root mean square error (RMSE). In order to deem a combination model as a more accurate forecast the RMSE must be lower than each of individual models. The first was a forecast that combined the results of the multiple regression with those of the time series decomposition. In this

	Mult. Reg.	Decomposition	Box Jenkins
RMSE	228,224.73	86,490.19	149,087.39
MAPE	16.95%	4.60%	7.95%
Adj. R ²	82.07%	97.49%	92.33%
	Mult. Reg/Decomp	Mult. Reg/Box Jenkins	Decomp/Box Jenkins
RMSE	150,346.29	126,922.42	114,838.02
MAPE	9.44%	7.19%	6.78%
Adj. R ²	92.20%	94.44%	95.45%
	Mult. Reg/Dec	comp/Box Jenkins	
RMSE	111	,446.32	
MAPE	6.76%		
Adj. R ²	95	5.65%	

Table4: Forecast Combination and Individual Forecast Comparisons

case, the RMSE has been reduced when compared to the multiple regression on its own, however, it is not minimized in comparison to the decomposition. The second combination was the multiple regression and the Box-Jenkins; the results show that the RMSE was less than both individual models. The third model, decomposition with Box-Jenkins, had reduced RMSE when compared to Box-Jenkins but not reduced when compared to the decomposition technique. All three techniques were combined to see if this would produce an error minimized forecast. The results show that the RMSE for combined was lower than both the multiple regression and the Box-Jenkins, however, the decomposition technique had a lower RMSE than the combined forecast.

When forecasts results of two or more models are combined to make a more accurate model, it is more reliable if a weight is assigned to each individual forecast rather than assuming an equal weight. This is because each forecast method utilizes different pieces of information and thus one may have more significance when combining the results. As the results above showed that the multiple regression with Box-Jenkins to be the best combination model, a further analysis of the results is conducted.

Audit Trail Coefficient Table (Multiple Regression Selected)			Audit Trail Coefficient	Table (Multiple Regre	ssion Selected)
Series Description	Coefficient	P-value	Series Description	Coefficient	P-value
VALUE	-10,970.00	0.80	VALUE	0.00	0.00
Box Jenkins	0.74	0.00	Box Jenkins	0.74	0.00
Multiple Regression	0.29	0.00	Multiple Regression	0.29	0.00
Accuracy Measures		Value	Accuracy Measures		Value
Mean Absolute Percentage	e Error (MAPE)	7.19%	Mean Absolute Percentag	e Error (MAPE)	7.24%
R-Square		94.59%	R-Square		94.59%
Adjusted R-Square		94.44%	Adjusted R-Square		94.43%
Root Mean Square Error		126,922.42	Root Mean Square Error		126,981.28

Table5: Results of Combined Forecast - Left with constant, Right with constant = 0

The left side of Table 5 has the initial results of the regression, showing a constant term that is insignificant at the 95% confidence level which means that this coefficient is not statistically different from zero. Therefore, a second regression is run in which the constant is forced to be equal to zero; the results are shown on the right side of Table 6. The new forecast model is as follows:

VALUE=f(Box-Jenkins Forecast, Multiple Regression Forecast)

Using the weights that have been determined in this regression, the permit values can be estimated as:

VALUE=0.74*Box-Jenkins Forecast+0.29*Multiple Regression Forecast

Using this model to forecast the permit value gives the results shown in Table 6. The forecast shown in this table are only for the 12 quarters of future forecast and the 12 quarters of in-sample forecast. This data was plotted against time, to show the cyclical nature of the permit values; see Figure 4. The in-sample forecast appears well fitted to the actual data. The next twelve quarters show a consistent wavelike pattern, with peaks in June/July each year and troughs in March/April each year.

Table6: Actual and Forecast Values for 2008Q2 - 2011Q1 and Forecast Values from 2011Q2 - 2014Q2

Forecas	t Multiple Regr	ession Selected
Date	Actual Value	Forecast Value
Jun-2008	2,387,726.67	2,203,279.66
Sep-2008	1,984,759.33	2,274,634.13
Dec-2008	1,231,931.33	1,526,045.92
Mar-2009	753,210.00	1,076,128.58
Jun-2009	1,640,773.33	1,473,953.49
Sep-2009	1,947,078.33	1,949,222.57
Dec-2009	1,899,402.00	1,705,857.36
Mar-2010	1,661,939.00	1,584,485.11
Jun-2010	2,439,672.33	2,804,588.41
Sep-2010	1,971,174.33	2,256,410.15
Dec-2010	1,534,728.33	1,702,776.65
Mar-2011	1,372,714.67	1,329,943.52
Jun-2011		2,156,229.96
Sep-2011		2,012,119.00
Dec-2011		1,586,028.75
Mar-2012		1,373,065.87
Jun-2012		2,183,275.05
Sep-2012		2,039,942.78
Dec-2012		1,607,535.84
Mar-2013		1,390,330.32
Jun-2013		2,210,320.13
Sep-2013		2,067,766.56
Dec-2013		1,629,042.93
Mar-2014		1,407,594.77

Figure 4: Actual and Forecast Values for 2008Q2 - 2011Q1 and Forecast Values from 2011Q2 - 2014Q2



Conclusion

The value of building permits for single family dwellings in Canada can be an important indicator of the state of the economy. The time series decomposition model demonstrated that the value of permits has a cyclical pattern which follows the business cycles of the economy. This can be shown to be very useful information as one can use these cyclical factors to anticipate when the next fluctuation in the permit values will occur. As the housing market tends to slump during an economic downturn the number of permits would tend to fall and thus so would the average value of permits for that period.

In addition, the decomposition shows that these values trend upwards, which shows that overall the value of single family dwelling permits will continue increasing over time, likely due to inflation and expansionary pressures in the economy. In addition, this model also demonstrated that seasonality exists in this data, specifically that the second and third quarter of each year has above average values while the first and last quarter of each year are below average. This makes sense as typically, depending on demographic location and seasonal temperatures, the number of permits during the summer months would be higher than the winter months and thus the values would reflect this pattern.

Considering that the Root Mean Square Error, the Mean Absolute Percentage Error (average forecast error) and the Adjusted R² values reflect that the Time Series Decomposition Model was the most accurate individual forecast technique. Table 7 shows the actual and forecasted values for 2008 Quarter 2 to 2011 Quarter 1 and the forecast values from 2011 Quarter 2 to 2014 Quarter 1.

These actual and forecasted values were plotted and shown in Figure 5. The graph is similar to the combined model in that the model quite accurately fits in-sample, and the pattern continues into the twelve quarters of the future with peaks and troughs in the July and April, respectively.

The combination of the multiple regression and Box-Jenkins forecasts produced the most improved forecast of all the combinations that were used. The multiple regression model made use of the relationships between the permit values and the exogenous factors that influenced it. To recap, the mortgage lending rates and unemployment had a negative relationship to the permit values, while GDP growth, inflation and population had positive relationship. It was determined that 82.07% of the variation in the values of permits was explained by the above variables. The Box-Jenkins model made use of the autoregressive integrated moving average which looked at the historical patterns in the data to predict what patterns the future values would

Table7: Actual and Forecast Values for 2008Q2 - 2011Q1 and Forecast Values from 2011Q2 - 2014Q2

Fored	ast Decomposit	tion Selected
	Actual Value	Forecast Value
Jun-2008	2,387,726.67	2,361,416.40
Sep-2008	1,984,759.33	1,835,710.71
Dec-2008	1,231,931.33	1,270,194.37
Mar-2009	753,210.00	1,078,020.48
Jun-2009	1,640,773.33	1,896,578.27
Sep-2009	1,947,078.33	1,833,496.99
Dec-2009	1,899,402.00	1,602,272.96
Mar-2010	1,661,939.00	1,534,593.90
Jun-2010	2,439,672.33	2,501,225.89
Sep-2010	1,971,174.33	2,043,847.53
Dec-2010	1,534,728.33	1,631,074.12
Mar-2011	1,372,714.67	1,446,222.44
Jun-2011		2,379,180.26
Sep-2011		2,036,582.78
Dec-2011		1,593,656.95
Mar-2012		1,438,941.93
Jun-2012		2,393,561.38
Sep-2012		2,044,623.80
Dec-2012		1,586,233.41
Mar-2013		1,439,009.92
Jun-2013		2,396,734.42
Sep-2013		2,044,940.25
Dec-2013		1,584,981.96
Mar-2014		1,439,274.74

Figure 5: Actual and Forecast Values for 2008Q2 - 2011Q1 and Forecast Values from 2011Q2 - 2014Q2



have, and determined a seasonal pattern existed. It was also concluded that 92.33% of the variation in the permit values was explained by the patterns existing in this data.

By combining the results of these two very useful sets of data, a more accurate forecast emerged which had a lower root mean square than the two models individually. In addition, by implementing this combination, it was determined that 94.43% of the variation in the permit values could be explained by the variables and patterns in the model. There are however, many other techniques and other variables that could be explored to further improve the accuracy of future forecasts in the value of residential building permits for single family dwellings in Canada.

Chart 1: White Test for Heteroskedasticity

Heteroskedasticity Test: White

F-statistic	1.745025	Prob. F(20,52)	0.0554
Obs*R-squared	29.31786	Prob. Chi-Square(20)	0.0817
Scaled explained SS	16.76430	Prob. Chi-Square(20)	0.6682

Test Equation: Dependent Variable: RESID² Method: Least Squares Date: 12/12/11 Time: 00:56 Sample: 1993Q1 2011Q1 Included observations: 73

Variable	Coefficient	Std. Error	t-Statistic	Prob.
с	-2.93E+13	2.99E+13	-0.979036	0.3321
MIR	2.09E+12	1.22E+12	1.709362	0.0933
MIR ²	-2.00E+10	1.51E+10	-1.324289	0.1912
MIR*INF	2.15E+10	4.07E+10	0.528784	0.5992
MIR*GROWTH	-2.08E+09	2.73E+09	-0.763535	0.4486
MIR*POP	-57564.75	31295.96	-1.839367	0.0716
MIR*UNEMP	-1.07E+10	1.71E+10	-0.627089	0.5333
INF	-1.46E+12	1.55E+12	-0.942260	0.3504
INF ²	-4.95E+09	4.09E+10	-0.120954	0.9042
INF*GROWTH	9.31E+09	6.11E+09	1.522303	0.1340
INF*POP	34058.15	37862.20	0.899529	0.3725
INF*UNEMP	3.70E+10	2.87E+10	1.287911	0.2035
GROWTH	3.81E+10	1.10E+11	0.345611	0.7310
GROWTH ²	2.10E+09	7.12E+08	2.946112	0.0048
GROWTH*POP	-1198.134	2723.562	-0.439914	0.6618
GROWTH*UNEMP	-2.69E+08	1.95E+09	-0.137899	0.8909
POP	1422107.	1519374.	0.935983	0.3536
POP ²	-0.016129	0.019418	-0.830637	0.4100
POP*UNEMP	-14752.86	19039.96	-0.774837	0.4419
UNEMP	5.00E+11	7.86E+11	0.636831	0.5270
UNEMP ²	-3.84E+09	7.72E+09	-0.497318	0.6211
R-squared	0.401615	Mean depende	ent var	5.62E+10
Adjusted R-squared	0.171466	S.D. depender	nt var	6.60E+10
S.E. of regression	6.01E+10	Akaike info crit	erion	52.71099
Sum squared resid	1.88E+23	Schwarz criter	ion	53.36989
Log likelihood	-1902.951	Hannan-Quinn	criter.	52.97358
F-statistic	1.745025	Durbin-Watsor	n stat	2.176178
Prob(F-statistic)	0.055352			

References

- Bank of Canada. (2010). *Bank of Canada*. Retrieved November 20, 2010, from http://www.bankofcanada.ca/en/index.html
- Fan, R. Y., Thomas, S., & Wong, J. M. (2011). Predicting construction market growth for urban metropolis: An econometric analysis. *Habitat International*, 167-174.
- Statistics Canada. (2010). Statistics Canada. Retrieved November 20, 2010, from http://estat.statcan.gc.ca.ezproxy.tru.ca/cgi-win/cnsmcgi.pgm?ESTATFile=ESTAT/ English/CII_1-eng.htm&Lang=E&RootDir=ESTAT/
- Tse, R. Y., Ho, C., & Ganesan, S. (1996). An Econometric Analysis of House Prices in Hong Kong. *Hong Kong: Department of Architecture, University of Hong Kong*.
- Wilson, J.H., and Keating, B. Business Forecasting with ForecastX. Sixth Edition. (2009) McGraw-Hill Companies, Inc.

CO₂ Sequestration Using Continuous Microalgae (Chlamydomonas sp.) Culture Linked in Series

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Abstract

The majority of current research on microalgae bioreactors is done so with the intent of maximizing algal biomass production, but very little research is done on optimizing CO_2 sequestration and observing the parameters that allow for this optimization. This study uses Chlamydomonas sp. grown in continuous culture in a triple photo-bioreactor system. The system receives a continuous supply of 5% CO_2 gas mixture, as well as fresh media delivered independently to each of the three bioreactors. By altering media flow rates and the corresponding growth rates of algae, CO_2 sequestration can be maximized. By adjusting light irradiance experienced by each bioreactor CO_2 sequestration can be further maximized. Culture density in each reactor was determined through analysis of chlorophyll concentration, this supported algal growth corresponding to the altered media flow rates. With initial media flow rates carbon was reduced to 3.81% by the time it exited the third reactor. After media flow rates were adjusted and light irradiance was optimized CO_2 sequestration was reduced from an initial 5.01% to 3.31% upon exiting the system. The overall purpose of this study is to develop a small-scale model that can be transitioned to an industrial application in hopes of reducing the high levels of gaseous carbon dioxide in our atmosphere.

Introduction

To date the majority of current research involving algal photo-bioreactors look to optimize algal biomass production, however very little research has been done in the realm of maximizing CO₂ sequestration. Considering the recent trends in global warming and with carbon levels at an all time high, this is rather alarming (Kossoy, 2010). Landfills and industrial smoke release points are some of the primary contributors towards these elevated levels of CO₂ and current methods using chemical based filtration ponds to mitigate this abundance in carbon simply results in more waste byproduct (Le Quere et al. 2009). Therefore a system must be devised that uses a more ecofriendly alternative in the capture of gaseous carbon dioxide. By developing a system that is capable of sequestering CO₂ emissions by use of modified algal bioreactors, it would be possible to eliminate current methods that are often counter productive, by the CO₂ released in burning waste byproducts. Therefore the purpose of this study is twofold: (1) Develop a closed triple photo-bioreactor system in which an algal culture of Chlamydomonas sp. can be grown in continuous cultures and (2) vary media flow rates to maximize carbon sequestration of 5.0% CO₂ gas mixture. Light irradiance will also be varied to further maximize carbon sequestration. The reasoning behind an in-series growth culture system would be to maximize CO₂ sequestration in a stepwise fashion at the various bioreactors. The overall design of this system will act as a small scale model that can be enlarged to suite an industrial application, such as mill smoke stacks and landfill gas effluent release points.

Materials and Methods

i) Bioreactor Set-up and CO, Monitoring

The bioreactor set-up was an altered form of a previous double reactor model (Nelson, 2011). In this model, the gas stream for three 250 ml graduated cylinders, which acted as the site of algal growth and carbon sequestration, were connected in series. To accommodate growth of the algae, peristaltic pumps were used exclusively at each bioreactor, supplying fresh media to the system while also withdrawing media consisting of algal biomass into waste beakers for future sampling. Continuous cultures were set-up in a manner, which allowed for growth rates to be controlled and have algae produced in a constant physiological state. The peristaltic pumps were required to ensure that pressure within each individual reactor was adequate to facilitate gas flow to the preceding reactor. As well as maintaining pressure the peristaltic pump allowed for the optimization of algal growth by adjusting pump

rates and consequently carbon sequestration. Light banks each fixed with fluorescent tubes were situated around the photo-bioreactor system. The lights remained on for the course of the experiment with the exception of irradiance adjustments. Further optimization of CO_2 sequestration was accomplished by independently adjusting the light irradiance at each reactor. Irradiance readings recorded by a LI-COR PhotometerTM were determined and adjusted for the positioning and amount that yielded the highest CO_2 sequestration and algal biomass. The CO_2 -air mixture was administered at 2.0 kPa to the system provided by cylinders, where CO_2 was accurately measured at 5.00 % \pm 0.01 and balanced with an adjacent supply of nitrogen. Split junctures located in the gas lines between reactors allowed for the addition of a QuibitTM systems CO_2 analyzer model No. S153, which could accurately record CO_2 levels while under full system operations. The bioreactors were maintained in a closed system to ensure both optimal carbon sequestration and limit unwanted contamination or growth (Figure 1).



Figure 1. Schematic diagram of triple photo-bioreactor setup containing continuous growth cultures of *Chlamydomonas* sp.

ii) Media Preparation

Preparation of media was done in five separate stocks to ensure that precipitation did not occur in the autoclaving process. The media was developed to meet all the growth requirements essential to the *Chlamydomonas* algal species. The pH of the media was held constant at pH 5 using phosphate buffering. Five concentrated stocks containing trace minerals were made (Table 1). They were then diluted in the final preparations of the media. All stocks were autoclaved in suitable containers and stored appropriately to inhibit any contaminant growth. A batch culture of *Chlamydomonas sp.* was pre-grown in the media, and added to each of the bioreactors in a homogenous mixture.

Table 1. Component of each media stock to be autoclaved independently.

Media component	Measured Dry Weight (g)
Stock 1 – 500 mL water	
MgSO ₄ · 7 H ₂ O	2.0
$CaCl_2 \cdot 2 H_2O$	1.0
Stock 2 – 250 mL water	
$K_2HPO_4 \cdot 3 H_2O$	1.8
KH ₂ PO ₄	68.1
Stock 3 – 500 mL water	
NaEDTA	0.15
Citrate	5.4
FeSO ₄ · 7 H ₂ O	0.9
St. 1.4. 500 1	
Stock 4 – 500 mL water	
H ₃ BO ₃	1.43
$MnCl_2 \cdot 4 H_2O$	0.91
$ZnSO_4 \cdot 7 H_2O$	0.11
NaMoO ₄ · 2 H ₂ O	0.19
$CuSO_4 \cdot 5 H_2O$	0.04
$Co(NO_5) \cdot 6 H_2O$	0.05
Stock 5* – 500 mL water	
NaNO ₃	42.5

*Concentration of 1M NaNO3

During the final preparation of media these five stocks were combined according to the volumes shown in Table 2 into separate containers to be diluted and autoclaved, thus further ensuring no bioreactor contamination (Table 2).

Table 2. Dilution preparation of media stock. (Nelson, 2011)

	Stock Dilution Ratios
Flask A	45 mL Stock 1 + 9 mL Stock 4
Flask B	45 mL Stock 2
Flask C	30.6 mL Stock 3
Flask D	$3x (15 \text{ mL Stock } 5 + 2940 \text{ mL H}_2\text{O})$

iii) Measuring Cell Density

Algal cell density was calculated in relation to chlorophyll concentration. Presumably the higher the chlorophyll concentration would be directly paralleled by an increased algal cell count. Isolation of the chlorophyll from the algal cell was first ensured to calculate total concentration. To do so, 1 ml samples were removed from the collection beakers situated at each reactor and placed in 1 ml microcentrifuge tubes. These samples were then centrifuged at 14000 rpm for two minutes. The supernatant was then discarded and the green algal pellet was re-suspended in 1 ml methanol and left to sit for 15 minutes allowing for chlorophyll extraction. After the allocated extraction time the solutions were then centrifuged at 14000 rpm for an additional two minutes. If the pellet still appeared green after the second centrifuge, it was resuspended and left to sit for another 15 minutes. The supernatant, containing the extracted chlorophyll was placed in new microcentrifuge tubes and all samples were measured three times for absorbance using spectrophotometer at 650 and 655 nm, zeroed with methanol. Chlorophyll concentrations were then determined using the following absorbance formula (Smith, 2010):

 μ g chlorophyll/ml=25.5(A650)+4(A665)

Determining the concentration values of chlorophyll enabled for an analysis of how changing media flow rates affected that of algal growth within the bioreactors. Chlorophyll concentration and cell count was also used to determine whether the system reached equilibrium before varying light irradiance and growth rate parameters.

vi) Statistical Analysis

To determine if parameter variation had significant effects on the differences illustrated in CO_2 sequestration a two-sample t-test with a 95% CI was conducted using Minitab 16[®]. Differences were considered significant when P-value was less than 0.05.

Results and Discussion

In the process of this experiment an in-line continuous culture algal triple bioreactor system using *Chlamydomonas sp.* was successfully constructed. By manipulating a previous double bioreactor system constructed by Darren Nelson at Thompson Rivers University in 2011, the triple bioreactor system in this experiment looked to sequester carbon even further (Figure 2).

i) Optimizing CO₂ sequestration by adjusting media inflow rates

From a previous study conducted by Nelson (2011), it was demonstrated that by starting with equal flow rates in each bioreactor, fresh media acts as a limiting factor in one reactor while the preceding reactor is limited by CO_2 . Therefore the initial starting points of media flow rates were adjusted for each bioreactor accordingly (Table 3).

Table 3. Media inflow rates at each 250 ml reactor for the initial and optimized (adjusted) flow rate.

	Bioreactor 1	Bioreactor 2	Bioreactor 3
Initial Flow Rate	75 ml/ day	252 ml/day	290 ml/day
Adjusted Flow Rate	100 ml/day	216ml/day	230 ml/ day

Table 3. Media inflow rates at each 250 ml reactor for the initial and optimized (adjusted) flow rate.

Carbon sequestration can be directly liked to the growth of the culture, so by adjusting the growth rates accordingly in each reactor (Table 3), in theory we will be maximize the amount of carbon sequestered. This is supported by not only the results provided by the CO_2 % readings but by that of the chlorophyll concentrations as well (Table 4).

Table 4. CO_2 concentration and chlorophyll concentration (averages) recorded after each bioreactor, for both the initial and the adjusted (optimized) media flow rate with a starting CO_2 concentration of 5%. See Table 3 for media flow rates.

	Bioreactor 1	Bioreactor 2	Bioreactor 3
Initial Flow Rate			
- CO2 (%)	4.55%	3.91%	3.81%
- [Chlorophyll]	2.04	1.62	1.31
(µg chlorophyll/ml)			
Adjusted Flow Rate			
- CO2 %	4.28%	3.28%	3.4%
 [Chlorophyll] 	4.06	5.32	3.67
(µg chlorophyll/ml)			

The efficiency of carbon sequestration by the algal bioreactors was improved with manipulation of the media inflow rates. Correspondingly when these media inflow rates were adjusted, algal culture growth rates changed as well to accommodate for the limiting factors provided within the system parameters. When increased from 75 ml/day to 100 ml/day, carbon sequestration improved by a difference of 0.27% and this was also supported by an increase in chlorophyll (2.0463 increase to 4.0558 μ g chlorophyll / ml). Although these carbon sequestration values appear minor, a two-sample t-test with 95% confidence interval supported the differences to be



Figure 2. Bioreactor setup with adjusted (optimal) media flow rates, in order to sequester maximal carbon.

significant (P = 0.01, n= 12). Similar results were also seen at bioreactor 2 and 3 when media flow rates were adjusted to the limiting CO₂ factor (Table 4). When bioreactor 2 reduced media flow rate from 252 ml/day to 216 ml/day, carbon sequestration was reduced by a difference of 0.63% and chlorophyll concentration respectively increased from 1.6161 to 5.3185 μ g chlorophyll / ml. When bioreactor 3 reduced media flow rates from 290 ml/day to 230 ml/day, CO₂ sequestration followed with a difference of 0.41%. The two-sample t-test also demonstrated significant differences (P = <0.05) in carbon sequestration from initial to adjusted media flow rates at both reactor 2 and 3.

ii) Further optimization of CO_2 sequestration by adjusting light irradiance Although the adjusting of media flow rates demonstrated apparent levels CO_2 sequestration, the triple bioreactor system has yet to yield the desired results. Therefore by adjusting light irradiance, an increase in photosynthetic activity would be ensured and ultimately CO_2 sequestration, when matched with optimal media flow rates, would yield even more profound results. By increasing the amount of photosynthetic active radiation we were able to adjust the light irradiance experienced at each reactor, the results are summarized in Table 5.

	Bioreactor 1	Bioreactor 2	Bioreactor 3
Light Irradiance	10.24	16.51	11.73
Initial (µmol/m ² /sec)			
- CO ₂ (%)	4.28%	3.8%	3.4%
Light Irradiance	12	26	30
Adjusted			
(µmol/m ² /sec)			

3.76%

3.31%

-CO2(%)

4.14%

Table 5. Initial and adjusted light irradiance values and CO_2 values at optimal media flow rates for bioreactors 1, 2 & 3.

As seen in table 5, a slight increase in light irradiance at each bioreactor also prompts an increase in CO_2 sequestration. However when the differences in CO_2 % values for varying light irradiance are compared via two-sample t-test, the results were shown to be insignificant (P=>5, in all cases). Although the difference is insignificant, the results were not unexpected. Microalgae, including *Chlamydomonas* saturate at a considerably higher irradiance than used in this experiment (Jacobi et al. 2012, Pillsbury, 1999).

Ultimately the results demonstrated in this experiment coincide with the objective that is; to construct an in line triple photo-bioreactor system that houses *Chlamydomonas sp.* and sequesters carbon to a respectable percent. The flexibility in small scale system should allow for many other parameters to be tested, and in theory, the addition of more bioreactors and manipulation of subsequent media flow rates may make it possible to sequester all of the CO_2 from gas. However before total CO_2 sequestration can be experienced many other factors must be addressed in the future to completely optimize the system. Most notably the triple photo-bioreactor system did not always maintain a homogenous mixture and most often we would experience algal settling on the bottom of the bioreactor. The settling that occurred may have been responsible for the increased levels of CO_2 released by the decomposition process. Sedimentation on the glassware may also inhibit the transparent

effects of the bioreactor, possibly counteracting the photosynthesis process and negatively affecting carbon sequestration (Pillsbury, 1999). Possible reasons pertaining to sedimentation of the algae, is the poor bubbling of gas released from the porous rock filter. The bubbles released in this process were small and lacked the ability to keep the bioreactor content at a homogenous mixture. A study done by Rocha and colleagues(2003) hypothesized that small bubbles lead to increased cell wall damage in algal species and therefore decrease growth rate and lead to algal decomposition sites in the bioreactor system. Although it was previously mentioned that light had little effect on the CO₂ sequestered in the system, we must note that the light plants were left on for the entirety of the experiment and this may have had negative consequences. Many algal species work best on a diurnal clock, and often experience chloroplast fatigue or bleaching when over exposed to the photosynthetic light (Pillsbury, 1999, Janssen, 1999).

Future research must first address the gas bubbling process experienced in the bioreactor system. The bioreactor must be able to maintain constant gas flow as well as a consistent bubble size throughout the whole system to avoid algal sedimentation. Furthermore it would be beneficial to develop a system that continually monitors the CO₂ levels over the duration of the study to gain more accurate data. To address the issue of possible chloroplast bleaching, it would be useful to introduce an intermittent light interval system, to increase the overall efficiency of the bioreactors (Janssen, 1999). Considering this is a small-scale model, the energy costs to run it are probably counterintuitive to the overall objective, however transition to an industrial scale model and the use of natural light on a diurnal system may be advantageous towards energy costs. Although there are already current methods in place to sequester carbon released from single pore gas effluent point, this in line series algal bioreactor system offers a more environmentally friendly solution in doing so, while providing little byproduct in the process. Any converted byproduct, is simply biomass of algae and water with trace minerals, and there are countless applications of algal biomass with regards to fertilizer, biofuels etc. Ultimately this study has shown that a small scale bioreactor system has the ability to turn an abundant waste product and convert it into something can be applied on many aspects.

Literature Cited

- Jacobi A, Bucharsky E. C., Schell K,G., 2012. The Application of Transparent Glass Sponges for Improvement of Light Distribution in Photobioreactors. J Bioprocess Biotechniq. 2:113
- Janssen M, Kuijpers TC, Veldhoen B, Ternbach MB, Tramper J, Mur LR, Wijffels RH. 1999. Specific growth rate of *Chlamydomonas reinhardtii* and *Chlorella sorokiniana* under medium duration light dark cycles: 13-87 s. J Biotechnol 70(1-3):323-33.
- Kossoy A, Amborsi Philippe. 2010 State and trends of the Carbon Market. Carbon Finance. pp 1-60
- Le Quere C, Raupach M.R., Canadell J.G., Marland G. 2009. Trends in the sources and sinks or carbon dioxide. *Nature Geoscience* (2) 831-836.
- Smith, R. (2010) Biology 3510 Laboratory Manual. Thompson Rivers University. Kamloops, BC. p. 21.
- Pillsbury RW and Lowe RL. 1999. The response of benthic algae to manipulations of light in four acidic lakes in northern Michigan. *Hydrobiologia* 394:69-81.
- Rocha JM, Garcia JE, Henriques MF, 2003. Growth aspects of the marine microalga Nannochloropis gaditana. Biomolecular Engineer. 20: 327-242.

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Does Inbreeding Depression Occur in the Sagebrush Buttercup (Ranunculus glaberrimus)?

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Biology

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Abstract

As habitat and population fragmentation increase in occurrence due to anthropogenic activities, decreasing health and fitness through inbreeding depression of affected populations becomes an increasing concern. Many plant populations utilize mixed mating strategies that allow them to temporarily overcome the hurdles of unfavourable conditions and maintain reproductive output. The aim of this research was to determine if a difference existed in the germination of selectively outcross-pollinated, selectively self -pollinated and naturally fertilized seeds of Ranunculus glaberrimus and whether origin from primary (first emerging) or secondary (later emerging) flowers played a role. Seeds collected in 2009 and 2010 from out-crossed, self-fertilized and naturally fertilized R. glaberrimus flowers were grown in germination chambers at controlled conditions. Germination of seeds was documented in order to determine whether flower type and/or reproductive mode played a significant role in the fitness of progeny. Results of this study showed that there was no overall significant difference in the germination rate of seeds despite a difference in reproductive mode and floral origin.

Introduction

Inbreeding depression is the decreased fitness of individuals in a population due to the mating of closely related individuals (Angeloni *et al.* 2011; Husband and Schemske 1996; Anderson *et al.* 1992; Charlesworth and Charlesworth 1987). A decrease in fitness can be exhibited through negative changes in plant traits such as germination, biomass and reproduction (Angeloni *et al.* 2011; Husband and Schemske 1996). However, the magnitude of adverse impacts on these traits varies according to population history and species characteristics such as life history, mating system, and longevity. Inbreeding depression is caused by the expression of deleterious, recessive alleles that become more prevalent in inbred populations (Angeloni *et al.* 2011, Husband and Schemske 1996, Anderson *et al.* 1992).

In conservation biology, inbreeding depression is a great concern as endangered species tend to be dispersed among small populations, which with time, become increasingly related. A meta-analysis done by Angeloni *et al.* (2011) confirmed that inbreeding in fragmented plant populations is a frequent and widespread occurrence. In light of this, inbreeding depression should be considered a growing threat to population stability as habitat fragmentation due to anthropogenic activities makes reproduction via outcrossed pollination rarer and more difficult to achieve.

As plants are unable to control the environmental conditions that surround them, many flowering species have evolved strategies to maximize their reproductive output despite unfavourable conditions (Eckert *et al.* 2010, Burd 1994). Such strategies employed by plants may include attuned flowering phenology and mixed mating systems. Flowering phenology relies on environmental cues such as temperature and daylight length to trigger the emergence of flowers at a time that coincides with the arrival of appropriate pollinators (Tooke and Battey 2010). Furthermore, sequential flowering of first emerging (primary) and later emerging (secondary) flowers extends this window of opportunity and provides a buffer against varying and adverse environmental conditions (*Cameron-Inglis et al.* 2011; *Simcox* 2011).

Mixed mating systems employ multiple mating strategies: out-crossing, selffertilization and apomixis. Out-crossing involves the transfer of pollen from one parent plant onto another parent plant and results in the most genetically diverse progeny. Self-fertilization occurs when the pollen of bisexual and selfcompatible individuals is able to fertilize their own ovaries. Apomixis results in asexual production of seeds in a process in which fertilization is not needed to occur. Since fertilization through outcrossing produces the most genetically diverse and stable progeny, it has the least chance of producing inbreeding depression. However, the occurrence of fertilization via outcrossing relies on factors such as the distribution and density of individuals as well as the distribution and behaviour of appropriate pollinators (Eckert et al. 2010). As human disturbances and climate change have the potential to decouple plant-pollinator relationships (Angeloni et al. 2011), out-crossing may become even more limited for some species. For those plant species that are bisexual and self-compatible with their own pollen, self-fertilization provides a means to overcoming such reproductive hurdles (Goodwillie et al. 2005). Nonetheless, self-fertilization does not provide an unproblematic solution. The progeny of self-fertilized flowers have been found to be notably weaker than their out-crossed counterparts due to the increased frequency of recessive and deleterious alleles (Charlesworth and Charlesworth 1987). Thus, although self-fertilization may provide a mode of reproduction when out-crossed pollen is limited, it may also lead to a heritable reduction in fitness of progeny caused by inbreeding depression.

Previous studies on *Ranunculus glaberrimus*, the Sagebrush Buttercup, examined the reproductive fitness of different mating strategies of this species and found that it could both outcross and self-fertilize (*Cameron-Inglis et al.2011; Simcox 2011*). The reproductive fitness (as estimated by the number of seeds per flower, mean seed mass, total seed mass and flower head mass) was compared between flowers limited to outcrossing, selfing or natural (unmanipulated) treatments. This comparison was made for both the primary and secondary flowers of *R. glaberrimus*. In these previous studies, the seeds of each flower were collected and weighed; however, no attempt was made to determination the germinability of seeds. The goals of this project were to examine whether: (1) differences in fitness could be observed in germination rates among out-crossed, self-fertilized seeds, and naturally-fertilized seeds and (2) if differences among these treatments were significant between seeds of primary and secondary flowers collected in the 2010 sampling year.

Materials and Methods

Flower Description

Rannunculus glaberrimus is a perennial herb commonly found inhabiting the dry grasslands, shrublands and open forests of Southern Interior British Columbia, Canada (Figure 1, E-flora 2012). The bright yellow, one-to four- flowered inflorescences of this species can appear first in March and can continue blooming into July (E-flora 2012). *R. glaberrimus* produces hermaphroditic flowers that are fully self-compatible, allowing for both self-fertilization and out-crossing to occur.



Figure 1. Map depicting the distribution of *R. glaberrimus* throughout British Columbia, Canada (E-flora 2012). Shaded areas show current distribution of *R. glaberrimus* North America.



Figure 2. Photograph of *R. glaberrimus*.

Seed Selection and Preparation of Germination Trials

Seeds used in this 2011 study were obtained in 2009 and 2010 from sampling during those growing seasons (Cameron-Inglis et al. 2010; Simcox 2011). During 2009 and 2010, upon daily visits to the R. glaberrimus population site (N 50°38'46", W 120°20'25"), the emergence date of flowers was documented as they were individually tagged and given identification codes. Fully reflexed flowers were given treatments that consisted of bagging, emasculation or no manipulation to produce self-fertilized, out-crossed or natural seeds respectively. During 2011, seeds collected from flowers during summers 2009 and 2010 were prepared for three different germination trials using methods adapted from Perry et al. (2005), Young et al. (1992) and May et al. (2011). Due to size limitations of the germination chamber, germination experiments had to occur in three different trials rather than one. Prior to this experiment, seeds were stored in sealed plastic bags in the dark and at room temperature. Ten seeds per treatment, from nine treatments varying in year of collection, type of flower (primary vs. secondary) and reproductive mode (Table 1) were randomly selected and individually sealed in an envelope. These seeds were cold stratified for 3 weeks in a freezer (below 0°C) to stimulate germination immediately prior to each of the three germination trials (May et al. 2011). After stratification, a 10% bleach solution was used to surface sterilize seeds in a 96-well plate for 10 minutes to minimize fungal contamination as a confounding variable Perry et al. (2005). Following sterilization, seeds were rinsed with deionised water and then transferred into 60 mm Petri dishes containing Whatman #41 ashless filter paper and 2 ml deionised water. The edge of each Petri dish was sealed with parafilm to minimize water loss. Seeds were then placed in a germination chamber for 3 weeks under a temperature set at 25°C and a photoperiod of 16 hours with light intensity ranging between 37- 102 μ Em⁻ ²s⁻¹. As light intensity was strongest at the center of the germination chamber, every second day Petri dishes were rotated to ensure that overall, they were receiving the same amount of light.

Table 1. List of nine year/flower type/reproductive mode treatments used in this study for each of the three germination trials.

Treatment	Year Collected	Flower Type	Reproductive mode
1	2009	Primary	Self-fertilization
2	2009	Primary	Out-crossing
3	2009	Primary	Natural
4	2010	Primary	Self-fertilization
5	2010	Primary	Out-crossing
6	2010	Primary	Natural
7	2010	Secondary	Self-fertilization
8	2010	Secondary	Out-crossing
9	2010	Secondary	Natural

Analysis of Seed Germination

After removal from the germination chamber, seeds were examined underneath a back lit dissecting microscope to determine whether germination had occurred. If fungal contamination was present, the seed was removed from further analysis.

Figure 3. Photograph of a radicle emerging from a germinating Sagebrush Buttercup seed



Results

Analysis of all Treatment Types

Using Minitab (version 16), Chi-squared tests for association were done to compare the number of germinated seeds from the self-fertilized, out-crossed and natural treatments within 2009 primary flowers, 2010 primary flowers and 2010 secondary flowers (Tables 2, 3 and 4). Analysis of germinated versus ungerminated seeds by treatment type in each trial (Tables 2, 3, and 4) produced insignificant results (p-value > 0.05) for seeds collected from 2009

primary, 2010 primary and 2010 secondary flowers. These results suggest that the origin of seeds (flower type, year collected and reproductive mode) did not play a significant role in the germination rate of seeds during any of the three germination trials.

Table 2. Comparison of germinated and non-germinated seeds among self-fertilized (SF), out-crossed (OC) and natural (NAT) treatments of the first germination trial. The 1° symbol designates primary flowers and the 2° symbol designates secondary flowers.

Year Collected	2009	2009	2009	2010	2010	2010	2010	2010	2010
Flower Type	1°	1°	1°	1°	1°	1°	2°	2°	2°
Reproductive Mode	SF	ос	NAT	SF	ос	NAT	SF	OC	NAT
# Germinated	5	6	7	1	3	2	7	7	7
# Not Germinated	4	3	3	8	7	9	3	2	1
Test Statistic	0.333			1.092			0.787		
P-value	0.846			0.579			0.675		

Table 3. Comparison of germinated and non-germinated seeds among self-fertilized (SF), out-crossed (OC) and natural (NAT) treatments of the second germination trial.

Year Collected	2009	2009	2009	2010	2010	2010	2010	2010	2010
Flower Type	1°	1°	1°	1°	1°	1°	2°	2°	2°
Reproductive Mode	SF	OC	NAT	SF	OC	NAT	SF	OC	NAT
# Germinated	1	2	3	1	3	2	0	4	3
# Not Germinated	7	8	7	8	7	9	9	6	5
Test Statistic	1.393			1.092			4.739		
P-value	0.498			0.579			0.094		

Table 4. Comparison of germinated and non-germinated seeds among selffertilized (SF), out-crossed (OC) and natural (NAT) treatments of the third germination trial.

Year Collected	2009	2009	2009	2010	2010	2010	2010	2010	2010
Flower Type	1°	1°	1°	1°	1°	1°	2°	2°	2°
Reproductive Mode	SF	ос	NAT	SF	OC	NAT	SF	OC	NAT
# Germinated	1	1	2	4	1	0	5	4	5
# Not Germinated	8	8	7	6	7	9	4	3	4
Test Statistic	0.587			5.296			0.005		
P-value	0.746			0.071			0.997		

In order to determine whether separate trials could be grouped together for subsequent analyses, Chi-squared tests of association were performed to see if there were significant differences in germination rates among trials (Tables 5, 6, and 7). The results of Tables 5, 6 and 7 reveal that trials could not be grouped together based on treatment type because trials either significantly differed from one another (p-value < 0.05), or a reliable test statistic could not be calculated (n/a).

Table 5. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) seeds from 2009 primary flowers among first, second and third trial sets.

Year Collected	2009	2009	2009	2009	2009	2009	2009	2009	2009
Flower Type	1°	1°	1°	1°	1°	1°	1°	1°	1°
Reproductive Mode	SF	SF	SF	ос	OC	ос	NAT	NAT	NAT
Trial #	1	2	3	1	2	3	1	2	3
Test Statistic	n/a*			0.281			0.148		
P-value	n/a*			0.596			0.701		

* \underline{n}/a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

Table 6. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) seeds from 2010 primary flowers among first, second and third trial sets.

Year Collected	2010	2010	2010	2010	2010	2010	2010	2010	2010
Flower Type	1°	1°	1°	1°	1°	1°	1°	1°	1°
Reproductive Mode	SF	SF	SF	ос	OC	ос	NAT	NAT	NAT
Trial #	1	2	3	1	2	3	1	2	3
Test Statistic	2.039			0.787			n/a*		
P-value	0.153			0.375			n/a*		

*<u>n</u>/a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

Table 7. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) seeds from 2010 secondary flowers among first, second and third trial sets.

Year Collected	2010	2010	2010	2010	2010	2010	2010	2010	2010
Flower Type	2°	2°	2°	2°	2°	2°	2°	2°	2°
Reproductive Mode	SF	SF	SF	oc	OC	oc	NAT	NAT	NAT
Trial #	1	2	3	1	2	3	1	2	3
Test Statistic	6.923			0.486			0.554		
P-value	0.009**			0.486			0.457		

*<u>m</u>/a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

Analysis of Germination in Primary versus Secondary Flowers

To establish whether germination rates varied among the seeds of secondary and primary flowers collected in 2010, comparisons of treatments were again done per trial through chi-square tests of association in Minitab (Tables 8, 9 and 10). Table 8. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) among seeds of 2010 primary and secondary flowers from trial set one.

Year Collected	2010	2010	2010	2010	2010	2010	2010	2010	2010
Flower Type	2°	2°	2°	2°	2°	2°	2°	2°	2°
Reproductive Mode	SF	SF	SF	ос	ос	ос	NAT	NAT	NAT
Trial #	1	2	3	1	2	3	1	2	3
Test Statistic	6.923			0.486			0.554		
P-value	0.009**	1		0.486			0.457		

* \underline{n}/a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

*** Marginal significance (α=0.05)

Table 9. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) among seeds of 2010 primary and secondary flowers from trial set two.

Year Collect	2010	2010	2010	2010	2010	2010	
Flower Type	1°	2°	1°	2°	1°	2°	
Reproductive Mode	SF	SF	OC	OC	NAT	NAT	
Test Statistic	n/a*		0.220		0.891		
P-value	n/a*		0.639		0.345		

* \underline{n} /a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

*** Marginal significance (α=0.05)

Table 10. Comparison of germinated and non-germinated self-fertilized (SF), out-crossed (OC) and natural (NAT) among seeds of 2010 primary and secondary flowers from trial set three.

Year Collect	2010	2010	2010	2010	2010	2010		
Flower Type	1°	2°	1°	2°	1°	2°		
Reproductive Mode	SF	SF	OC	OC	NAT	NAT		
Test Statistic	n/a*		0.220		0.891			
P-value	n/a*	n/a*		0.639		0.345		

*<u>m</u>/a designates the inability of Minitab to calculate a reliable test statistic due to small sample size (values less than 5).

**Significance (α=0.05)

*** Marginal significance (α=0.05)

Comparisons of secondary versus primary flower germination by treatment yielded inconclusive results. Although marginally significant and significant results were obtained (Table 8 and 10), they provided little information as they were not replicated among other trials. In trials 1 and 3 (Tables 8 and 10, respectively), it is apparent that natural treatments yielded significantly higher germination rates for secondary versus primary flowers.

Discussion and Conclusions

In this research, seed origin was found not to play a significant role in the germination rate of seeds. Neither mode of reproduction, type of flower, nor year of production influenced the rate of germination. Despite germination being plant attribute that has been shown to be influenced by inbreeding depression (Angeloni *et al.* 2011, Husband and Schemske 1996, Anderson *et al.* 1992, Charlesworth and Charlesworth 1987), there are several considerations regarding this research which needs to be taken into account.

Individual trials could not be grouped together either due to significant differences in germination rates within treatment types, or computational problems stemming from small sample size (Tables 5, 6 and 7). Therefore, analysis of data was greatly constricted and had to rely upon Chi-squared tests of association to determine if differences exist between out-crossed and self-fertilized seeds of individual trials.

The absence of significantly lower germination rates for self-fertilized seeds suggests that this mode of reproduction does not affect the germination rate of subsequent offspring. Nonetheless, insignificant results do not imply that self-fertilization has not led to inbreeding depression in these offspring.

As natural treatments were left unmanipulated, the mode of reproduction or proportion are unknown; therefore, inferences on inbreeding depression cannot be made. However, for these trials, it appears that the secondary flowers given natural treatments produced more vigorous offspring due to higher germination rates. Similarly, secondary flowers were found to have significantly higher germination rates when limited to out-crossing in the third trial (Table 10). However, as this result is present in only one trial, this finding should be viewed with caution until further work can replicate this result.

The lack of evidence for inbreeding due to self-fertilization in this experiment does not exclude inbreeding depression in this species. Several factors not controlled for in the experimental design of this research may have masked the effects of inbreeding depression in our results. First, inbreeding depression relies on the characteristics and expression of homozygous, deleterious alleles. Varying dominance of these alleles and their role in life stages of an organism may make them difficult to detect (Angeloni et al. 2011, Husband and Schemske 1996, Anderson et al. 1992). For instance, they may have been too weak to be distinctively expressed, or they may simply not have acted in the germination stage, which was the stage examined in this research. Second, substantial accumulation of deleterious alleles may not occur without continued inbreeding among several or more generations. As demonstrated by Anderson et al. (1992), the effects of inbreeding depression become more drastic with subsequent self-fertilization, generation after generation. As the ability of *R. glaberrimus* to outcross as well as self-fertilize is known, there is no reason to believe that this population has been inbreeding repeatedly (Cameron-Inglis et al. 2011; Simcox 2011). Third, varying germination rates due to the absence and presence of inbreeding among out-crossed and self-fertilized offspring, respectively, may not be evident in optimal growing conditions such as those obtained in a germination chamber. As inbreeding bestows a lower fitness upon offspring, this phenotypic difference may not be detrimental to survival until a selective pressure is applied (Armbruster and Reed 2005). Last, Byers and Waller (1999) suggest that populations which have a history of inbreeding may have purged deleterious alleles. As homozygotes become increasingly common in such populations, selection against individuals with lethal and sub-lethal alleles effectively purges these traits out of the population. However, prior studies (Cameron-Inglis et al. 2011; Simcox 2011) have found that this R. glaberrimus population readily outcrosses, making "allele purging" an unlikely effect.

Suggestions for future work

While the results of this research have provided only limited evidence that reproductive mode, year of production and type of flower substantially affects germination, they have revealed potential avenues for future work. First, inbreeding depression should be examined across various life stages that extend past germination such as seedling establishment and growth. Second, employment of stressful versus non-stressful growing regimes may make the effects of inbreeding depression more apparent. Third, the statistical analyses of this project were greatly constrained by limitations of small sample size. By increasing the number of samples per trial, this problem may be avoided. Last, investigating the proportions at which outcrossed and self-pollination occur in unmanipulated conditions could shed light on the reproductive strategies of *R. glaberrimus*.

References

- Anderson N. O., P. D. Ascher and R. R Widmer. 1992. Inbreeding depression in garden and glasshouse chrysanthemums: germination and survivorship. Euphytica. 62: 155-169.
- Angeloni, F., N. J. Ouborg, and R. Leima. 2011. Meta-analysis on the association of population size and life history with inbreeding depression in plants. Biological Conservation. 144: 35-43.
- Armbruster, P., and D.H. Reed. 2005. Inbreeding depression in benign and stressful environments. Heredity **95**:235-242
- Burd, M. 1994. Bateman's principle and plant reproduction: the role of pollen limitation in fruit and seed set. The Botanical Review **60**: 83-139.
- Byers, D. and Waller, D.M. 1999. Do plant populations purge their genetic load? Effects of population size and mating history on inbreeding depression. Annual Review of Ecology, Evolution, and Systematics. 30:479-513.
- Charlesworth, D., and B. Charlesworth. 1987. Inbreeding depression and its evolutionary consequences. Annual Review of Ecology and Systematics **18**: 237.
- Cameron-Inglis, H., M. Jones, A. Simcox, A. Percell and L. Baldwin. 2011. Timing it right: reproductive flexibility in an early-flowering plant (*Ranunculus glaberrimus*). Unpublished manuscript.
- Eckert, C., Kalisz, S., Geber, M., Sargent, R., Elle, E., Cheptou, P.-O., Goodwillie, C., Johnston, M., Kelly, J., Moeller, D., Porcher, E., Ree, R., Vallejo-Marin, M., and Winn, A. 2010. Plant mating systems in a changing world. Trends in Ecology and Evolution 25(1): 35-43.
- E-Flora. 2012. http://www.geog.ubc.ca/biodiversity/eflora/. [accessed April 2, 2012].
- Goodwillie C., S. Kalisz and C. G. Eckert. 2005. The evolutionary enigma of mixed mating systems in plants: occurrence, theoretical explanations, and empirical evidence. Annual Review of Ecology, Evolution and Systematics. **36**: 47-79.
- Husband B. C., and D. W. Schemske. 1996. Evolution of the magnitude and timing of inbreeding depression in plants. Evolution. 50: 54-70.
- May, L., and Baldwin, L. 2011. Linking field based studies with greenhouse experiments: the impact of Centaurea stoebe (=C. maculosa) in British Columbia grasslands. Biological Invasions. 13: 919-931.
- Perry, L.G., C. Johnson, E.R. Alford, J.M. Vivanco and M. Paschke. 2005. Screening of grassland plants for restoration after spotted knapweed invasion. Restoration Ecology. 13: 725-735.
- Simcox A. 2011. Secondary flower contribution to the evolutionary fitness of the sagebrush buttercup (*Ranunculus glaberrimus*). Unpublished manuscript.
- Young, J. A., E. Martens and N. E. West. 1992. Germination of Bur Buttercup Seeds. Journal of Range Management. **45**: 358-362.
- Tooke, F. And N. F. Battey. 2010. Temperate flowering phenology. Journal of Experimental Botany. **11**: 2853-2862.

Analysis of Optical Response and Morphological Dimorphisms of Gender Morphs in an Androdioecious Population of *Ranunculus glabberimus* ssp. *ellipticus*

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Abstract

A population of androdioecious Ranunculus glaberrimus ssp. ellipticus was analyzed for gender morph abundance, sexual structure abundance, and dimorphism in reflective spectra. The abundance of sexual morphs was calculated to be 0.94 males to 32.7 hermaphrodites (N_{plot} = 54 and N_{flower} = 1819). Hermaphroditic morphs had both carpels (µ=115.8±38.6) and stamens (µ=23.3±7.92), where male morphs had only stamens (µ=41.8±13.06). Male morphs also contained a structure embedded within the stamens at their base that was not seen in the hermaphroditic morph and possessed no apparent reproductive function. Analysis of reflectance spectra gave no significant difference between mean brightness, hue, and saturation values for the hermaphroditic and male morphs. The values for brightness were, 0.205 (Hermaphrodite) and 0.198(Male); values for hue were 0.714(Hermaphrodite) and 0.696(Male); and values for saturation were 0.454 (Hermaphrodite) and 0.455(Male).

Introduction

Ranunculus glaberrimus ssp. ellipticus, commonly known as sagebrush buttercup, is a gender dimorphic perennial plant that is native to BC's interior western grasslands. Surveys conducted by the author in the spring of 2010, 2011, and 2012 revealed that populations of this subspecies within Lac Du Bois Provincial Park were androdioecious - containing male-only and hermaphroditic flower morphs (unpublished data). Plant-pollinator interactions are an integral part in the long-term perpetuation of many species of flowering plants (Barrett 2010, Horandl 2008, Ashman 2005, Dafni 1992). For plants maintaining androdioecy, visual and olfactory cues contributing to plant-pollinator interactions become increasingly important (Ashman 2005). Androdioecy is an uncommon breeding system in angiosperms (Barret 2010, Majetic 2009, Ashman 2005) and the sagebrush buttercup breeding system has only been previously reported as gynodioecious with female-only and hermaphroditic flowers (Lloyd 1975, Cameron-Inglis 2011, Simcox 2010). Androdioecy is typically driven by negative frequency-dependent selection (Barret 2001), where the relative fitness of the rarer gender must be higher than that of the more common gender. In a buttercup whose pollination system depends on generalist pollinators (Simcox 2010), the fitness of the male morph must be maintained by an increase in attractive traits greater than or equal to 200% higher than the hermaphroditic morph; such as the abundance or quality of visual or olfactory cues (Ashman 2005). If the pollination system, including attractive traits, is not the sole maintaining factor for the male-morph within an androdioecious population other traits such as greater pollen fecundity of males or other genetic or inherited traits must be present (Lloyd, 1975).

Here, we analyze visual cues including abundance of reproductive parts, and petal reflectance, and compare these analyses to the frequency of male occurrence within the Lac du Bois population. This was done in order to determine if male flowers rely on unique visual cues to promote pollinator visits, and in an attempt to elucidate a correlation between abundance of sexual morphs and dimorphism of petal reflectance in this rarely observed system.

Materials and Methods

Species information

Ranunculus glaberrimus ssp. *ellipticus* have one to four flowered cymes, prostrate stems of moderate height (5-15cm), and lance shaped leaves (figure 1)(Parish 1996, Brayshaw 1989). Flowers are radially symmetric with an average of five petals (unpublished data) that are glossy, hairless, and

distinctly yellow. Flowers also have five sepals and a nectary at the base of the petals. Petals are typically composed of three layers of mesophyll parenchyma cells enclosed by a planar non-papillate epidermal surface, an oil-containing adaxial epidermis, and a starch grain rich adaxial mesophyll layer (Vegnioloni 2011). The epidermal surface is the layer containing the pigment (Vegnioloni 2011). Hermaphroditic morphs have a floral center with stamens (mean stamen number ~ 23) surrounding a concentric whorl of carpels (mean carpel number ~ 115) (figure 1). Male morphs have a concentric whorl of stamens (mean number of stamens ~ 41) surrounding a small elongate green mass not previously reported in literature (figure 1). *Ranunculus glaberrimus* ssp. *ellipticus* is typically found on dry hillsides (Klinkenberg 2008) and is one of the earliest flowering plants of the Southern Interior (Parish 1996). It is local to dry Ponderosa/Douglas-fir forests, as well as meadows and rock, grass, and sage slopes (Parish 1996) (figure 1-II).



Figure 1. Picture of the two gender morphs of Ranunculus glaberrimus ssp. ellipticus with male morph (IA.) and Hermaphrotic morph (IB.) Figure 1-II shows population with surrounding species

Lac Du Bois site description

The research site is located within Lac Du Bois Provincial Park at the 13km mark on the Lac Du Bois forest service road on a southwest-facing slope 300 m from the road (figure 2). Surrounding vegetation includes grasses (ex. *Agropyron spicatum*), sage (ex. *Artemisia tridentate*, an established Aspen stand downslope, and Douglas fir within 200m upslope (figure 1-II).

Kamloops (which includes Lac du Bois Provincial Park) has a dry arid climate with low precipitation (Lloyd 1990), the study area is located within the Fraser Plateaux and is described as having irregular topography of small benches and gullies (Van Ryswyk 1963).


Figure 2. Location of research site, 13km mark on Lac du Bois Forest Service Road indicated by star (50° 47.742 x 120° 26.566). Gender morph information was collected from 54 random 2mx1m plots, flowers were collected, bagged individually and frozen for later analysis (Adapted from a Google Earth overlay on a map from Ministry of Forests, 2012)

Although this area is open to the public it did not seem to have been visited as the trails are lower in the park and typically feed into the many lakes. However, there is free-range grazing within the park and there was some fecal evidence that cattle had grazed the area.

Fifty-four 2mx1m rectangular plots were sampled in the spring of 2011. Plot placement was randomized by throwing the PVC pipe plot over my shoulders after turning 90° to the right starting at coordinates 50° 47.742 x 120° 26.566. The total number of each flower morph was recorded for each plot, as well as the coordinates of each plot. Samples were collected from plots, sealed separately in Ziploc bags with quadrat and morph identifications on each bag (ex. Q21H would be a hermaphroditic flower from the 21st quadrat), and frozen.

Flower morphological analysis

Frozen samples were thawed after which stamens, carpels, and petals were counted for each collected flower. Analysis was done with a dissecting scope, carpels and stamens were counted twice to ensure accurate analysis. Petals were mounted onto a flashcard by using a small drop of deionized H₂O; this flattened the petals and allowed the petal to form a good optically

flat surface for spectral analysis. To avoid dehydration the mounted petals were carefully placed into a Ziploc bag, laid on a flat tray and refrozen for later spectroscopic characterization. Pollen counts were attempted using methodology from Cameron-Inglis (2011); however, above 95% of anthers had dehisced rendering the analysis inadequate. The counts were done by cutting the anthers along the line of dehiscence with a scalpel while the anther was submersed in a drop of deionized water. The pollen was extracted using a small prong and the pollen/water solution was washed into a centrifuge tube. 3 drops Ethylene blue and one drop detergent were added to the tube and the mixture was vortexed. A drop of the final vortexed mixture was then added to a haemocytometer and pollen was manually counted under a microscope.

Spectral characterization

The brightness, saturation, and hue of the collected *Ranunculus glaberrimus* ssp. *ellipticus* petals were quantified using methods similar to Vignolini and coworkers (2011), macroscopic scale reflectance spectra of normal incidence were obtained with an Ocean Optics Standard Reflection/Backscattering Probe connected to a light source and the Ocean Optics JAZ spectrometer. Reflectance spectra were normalized using the provided Ocean Optics White Standard, and a Dark Standard made from a black construction paper tube. The dark standard was set with the lamp turned off. The reflectance spectra wavelength range was set from 300-700nm by setting the range on the halogen lamp. Standards were re-set after the completion of one petal and before the analysis of the next petal. Three reflectance spectra were obtained for each petal, and three petals were analyzed at random from each collected flower. Petals were randomized by numbering the petals and drawing numbers out of a hat.

Statistical analysis

Statistical analysis was performed using R version 2.14 and further analysis was done with Minitab, using a standard t-test.

Results

Population dynamics

The fifty four quadrats that were sampled had a mean number of 0.94 males and 32.74 hermaphrodites per plot. There were 1768 total hermaphroditic flowers counted within these quadrats and 51 male-only specimens.

Flower morphology

Ranunculus glaberrimus ssp. *ellipticus* flowers were identified successfully as having two discrete sexual morphs. The hermaphroditic morph had stamens (μ =23.3±7.92) surrounding a concentric whorl of carpels (μ =115.8±38.6) (Table 1: figure 1 Right). Stamens were surrounded by petals (μ =5.80±1.06) and sepals. It should be noted that freezing caused too much damage to obtain mean sepal number data (Table 1).

Table 1. Morphological traits for hermaphroditic and male buttercup morphs collected from Lac
du Bois grassland population of <i>Ranunculus glaberrimus</i> ssp. <i>ellipticus</i> , collected and frozen
April 2011, thawed and analyzed February 2012 (N=23)

	Petal Number		Stamen Number		Carpel Number	
	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Hermaphrodite	5.80	1.06	23.3	7.92	115.8**	38.6
Male-Only	5.30	1.54	41.8**	13.1	-	-

**= P < 0.001 – showing a statistically significant difference between of Hermaphrodites and Male-Only morphs, and a statistically significant difference between in Hermaphrodites and Male-only morphs



Figure 3. Pictures of the Ranunculus glaberrimus ssp. ellipticus male-only morph (A.) Live flower from Lac du Bois population (B.) Male-only morph saturated with dH2O after being thawed, sepals are pulled back and unknown non-reproductive structure is brought forward with forceps notice conical extension from center of structure

The middle of the structure had an elongate conical portion that extended past the fused portion of structure described above (figure 3B), this elongate structure did not pull apart as the outer portions did and appeared to be a solid shoot of which function is unknown. Male-only morphs also had a mean petal number similar to the hermaphroditic morph (μ =5.30±1.54) and had sepals. Again, freezing caused too much damage to obtain mean sepal number data.

Reflectance signatures

As seen in figure 3(A, B) the petals have a distinctive yellow color, and reflectance is clearly visible in figure 3B. As such, the reflectance spectra for both morphs were quantified in an attempt to elucidate a dimorphism in reflectance between the two sexual morphs. Three reflective spectra were obtained and averaged to generate a mean value of brightness, saturation, and hue for each petal, these means were then used to calculate mean values for each flower, and averaged again to obtain an overall mean for brightness, saturation, and hue values for the hermaphroditic and male-only morphs (table 2).

Table 2. Reflective spectrometry data for hermaphroditic and male buttercup morphs collectedfrom Lac du Bois grassland population of *Ranunculus glaberrimus* ssp. *ellipticus*, collected andfrozen April 2011, thawed and analyzed February 2012 (N=23) reflective data for each spectra,each petal, and each flower can be found in appendix

	Brightness	Saturation	Hue	
Hermaphrodite	0.205	0.454	0.714	
Male-Only	0.198	0.455	0.696	

A reflective low was seen between 400-500nm and a reflective dip was seen in the 650-700nm wavelength band in all spectral plots (figure 4: A, B). The wavelength range used was 300-700nm.



Figure 4. Spectral plots of percent reflectance versus wavelength for hermaphroditic (B.) and male (a.) morphs. Each graph contains nine lines which represent the three analyses per petal, and three petals analyzed per flower (RAGL Numbers) at normal incidence.

Discussion

The population dynamics described by the results support the hypothesis that there is a dimorphism in gender morph occurrence within the Lac du Bois *Ranunculus glaberrimus* ssp. *Ellipticus* population with the hermaphroditic morph being 3482% more abundant than the male-only morph. The flower morphological data showed that the mean number of stamens was significantly higher in the male-only morph than the female morph and that the male-only morph did not contain carpels, instead it had a small fused structure embedded at the base of the stamen mass.

Analysis of the spectral plots allowed for the determination of absorption and therefore the presence of characteristic reflective signatures of particular compounds. The reflective low seen within the 400-500nm wavelength band in the spectral plots is due to the presence and absorption of carotenoid pigments (Vignolini 2011), the reflective dip seen in the 650-700nm wavelength band is due to the presence and absorption of chlorophylls (Karp 2009). The wavelength range was set to 300-700nm; In future analysis the region between 250-300nm would be included in the set range since the UV region spans 250-400nm. However, judging from the reflective spectra between 300-400nm for both morphs, there is no UV signature seen, unless of course a peak between 250-300nm was present and not visualized by the chosen range. Again, this may change with the analysis of fresh and not frozen samples.

This research showed that there was no significant difference in optical response between the frozen petals of the two sexual morphs. However, if this reflective spectrometry research was to be done with live samples, using the methods used by this study, a different result may be obtained. An analysis of current research did not identify if freezing specifically effected analysis by reflective spectrometry of the *Ranunculus* petal, Vignolini and co-workers were the only published researchers who analyzed the *Ranunculus* petals by reflective spectrometry and there samples had been cut and the stalks put into water until an analysis was done within a few hours of collection. However, there were several studies of the damaging effects of freezing to live plant tissues but not specifically to petal tissues of angiosperms (Gregory 2001, Paynado 1979). This damage could be quantified if the results of this research were compared to the results of research done with fresh/live samples.

Additional research with this population could results in the identification of the visual, olfactory, or combination of visual-olfactory cues that maintain

this population. An analysis of the epidermal layers of this species of *Ranunculus* by scanning electron microscope could be done using methods used by Vignolini and co-workers (2011). From that analysis, reflective spectra can be obtained from each of the epidermal layers and also compared between morph for dimorphism in both optical response and dermal layer abundance and thickness. A correlation could be made between the thickness of the epidermal layer and the amount of pigment within the petal, since it is this layer that is said to house the petal pigmentation. From this proposed research, a dimorphism between gender morphs could be quantified in conjunction to an analysis of pollination syndromes for petal dermal layers, thickness of epidermal layer, pigment abundance, and the optical response of similar dermal layers.

In order to try and determine if olfactory cues are the source of the dimorphism further analysis could be done on volatile emission. This could be done using GC-MS dynamic and static headspace analysis methods developed and presented by the author of this study to the Thompson Rivers University CUEF research council from methods used in Ashman et al (2005). From this volatile analysis, a potential dimorphism in overall volatile profiles emitted from both of the gender morphs could be quantified. By comparing this data (from live samples) to data obtained from spectral analysis proposed above, and further comparing this to the abundance data obtained in this study, a good grasp on visual and olfactory cue dimorphism could be made.

Further research could also elucidate a correlation between the gender dimorphism and specific inherited or genetic trait or traits. This could be done using TRU's IonTorrent sequencer on seeds. This type of analysis can be used to determine parental origins and ultimately lead to an analysis of whether the production of males is a result of the genetics or a genetic defect of the hermaphrodites by sequencing the genomic DNA housed within the seed. Additional work could be done to determine how many flowers were produced per plant, including both primary and secondary flowers, and whether one morph was being produced as a primary and one as a secondary or if there were no correlations here.

In conclusion, this study was able to derive a dimorphism in gender morph occurrence within the population of Lac du Bois *Ranunculus glaberrimus* ssp. *ellipticus*, this dimorphism was a staggering 32:1 in favor of the hermaphroditic morph. Although the reflective analysis was unable to derive a dimorphism, I am confident work done on live samples may have different results, as well as future work on olfactory cues and pollination syndromes held by this

population. This work has been incredibly interesting since the sexual system is so rare, and further work would be incredibly rewarding, thank you very much for the opportunity.

Acknowledgments

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Literature Cited

- Barret, C. 2010. The evolution of plant sexual diversity. Nature Review Genetics 3:275-284.
- Brayshaw, T. 1989. Ranunculus glaberrimus Hooker. Pages 120-122 in Buttercups, waterlilies, and their relatives in British Columbia, 1st edition. Royal British Columbia Museum, Victoria, BC.
- Cameron-Inglis. 2011. Honours Report, Thompson Rivers University.
- Dafni, A. 1992. Pollination ecology: a practical approach. IRL Press at Oxford University Press, Oxford [England] ;New York.
- Gregory, C., A. Knapp. 2011. Leaf optical properties in higher plants: linking spectral characteristics to stress and chlorophyll concentration. American Journal of Botany. 88(4): 677-684.
- Horandl, E. 2008. Evolutionary implications of self-compatibility and reproductive fitness in the apomictic Ranunculus auricomus polyploid complex (Ranunculaceae). International Journal of Plant Sciences 169:1219-1228.
- Karp, G. 2005. Cell and Molecular Biology: Concepts and Experiments. Book. (Figure 6.8, pg 213)
- Kearns, C., D. Inouye. 1993. Techniques for pollination biologists. University Press of Colorado, Niwot Colo.
- Klinkenberg, B. 2008. E-Flora BC Vascular Plant Atlas Page. Retrieved January 16, 2011, from http://linnet.geog.ubc.ca/Atlas/Atlas.aspx?sciname=Ranunculus%20 glaberrimus%20var.%20ellipticus&redblue=Both&lifeform=7
- Majetic, C.J., R. Raguso, T-L. Ashman. 2009. The sweet smell of success: Floral scent affects pollinator attraction and seed fitness in Hesperis matronalis (Brassicaceae). Functional Ecology. 3: 480-487.
- Ashman, T-L., D.H. Cole, M. Bradburn, R.A. Raguso. 2005. Scent of a male: the role of floral volatiles in pollination of gender dimorphic plant. Ecology 86: 2099-2105.
- Lloyd, D.G., and British Columbia. 1990. A Guide to site identification and interpretation for the Kamloops Forest Region. Ministry of Forests, Victoria B.C.
- Lloyd, D.G. 1975. The maintenance of gynodioecy and androdioecy in angiosperms. Genetica 45:325-339.
- Parish, R., R. Coupe, D. Lloyd. 1996. Plants of Southern interior British Columbia. Lone Pine Publishing. 463 p.
- Paynado, A., H.W. Gausman, D.E. Escobar, R.R. Rodriguez, M.V. Garza. 1979. Evidence of cell membrane injury detected by reflectance measurements. Cryobiology 16(1): 63-68.
- Van Ryswyk, A.L. 1965. Growth, productivity and chemical composition of a sub-alpine meadow in interior British Columbia. Journal of Range Management. 16: 235-240.
- Simcox, A. 2010. Unpublished Data.
- Vignolini, S., M. Thomas, et al. 2011. Directional scattering from the glossy flower of Ranunculus: how the buttercup lights up your chin. Journal of the Royal Society Interface. 1-7.

Canadian Afghanistan War Artist: Canadian Forces Artists Program (CFAP)

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Abstract

Canada has had a long history of having its artist record the wars it Dominion was involved in. Lord Beaverbrook enormous collection from the First World War of the Canadian government has shown a particular interest to record the efforts of its soldiers. This continues today with the efforts of the Canadian Forces Artist Program (CFAP), which has artist documenting the war. One of the most inspirational artist is Karen Bailey who recorded in acrylic work that of Canadians behind the line. As Bailey travelled to Kandahar to interact with the subjects of her work and liked to focus on the people behind the lines, so too did I seek the core of my research, the mind behind the work that inspires and awakens so many. In her book Triage, Bailey discusses her first exposure to wounded soldiers, civilians, and to her shock children. Bailey created a story that needed to be told.

Introduction

Canada was the first country in establishing a war art program with the creation of the Canadian War Memorial Fund in 1916, which was established by Lord Beaverbrook (Max Aitken) and Rothermere under the direction of the Canadian War Records office of the Canadian Army during WWI.¹ This fund commissioned, created and exhibited over 800 works, which were shown in exhibits after the war had ended.² With the end of the WWI the fund had ended and it wasn't till WWII that once again there was a need to document the war, which is when the Canadian War Records Program started. This program was similar to that of the Canadian War Memorial Fund, but the only differences were that Canadian artist serving were employed and that the works of art were exhibited during the war, which allowed civilians to see what was happening during the war, but once again as the war ended, Canada was once again had to official war art program.

From 1968-1995, the Canadian Armed Forces Artist Program (CAFAP) was built on the same principles of the two other programs. With keeping with the same aims as the previous two programs, this program allowed for civilian artist to apply for this program, and work alongside Canadian soldiers on both domestic and oversea operations. This program was cancelled in 1995 due to the lack of funds. On June, 6, 2011, announced the creation of the Canadian Force's Artist Program (CFAP).³ This new program allowed Canadian artist the opportunity to record Canada's soldiers around the word, which would "usher in a new era of Canadian military art."⁴

Karen Bailey was one of a few artists that applied to enter the Canadian Force's Artist Program. She focused on painting under-recognized members of society in Afghanistan at the *Triage* Hospital, based at the Kandahar Air Field (KAF). The extent of study that resulted from my method of interaction with the artist through email allowed for me to get firsthand accounts of Bailey's extraordinary experience with war and her techniques of expression, information which is difficult to find in articles and books. As I began e-mailing Bailey I started to build a relationship with her, which allowed for depth in my representation of her work.

Bailey is a graduate of the Reigate School of Art and Design in England. Her work prior to becoming an artist of the CFAP to 2007 included courtroom drawings for Global Television, book illustrations for Appletree Press, of the UK, and some other small projects. Bailey has received the prestigious Elizabeth Greenshield Fountain Grant twice for her drawings and paintings. Her work has been exhibited in Britain, Ireland, the United States of America, and Canada. She often portrays people and through her work she seeks to represent beauty, honesty, and humanity. As "a painter, [she] has focused on people who work behind the scenes and generally go unnoticed."5

After being accepted into the CFAP, Bailey had to fill out a ten page obligatory insurance form, prior to being allowed to go to Kandahar. She was motivated by Karole Marois who is also a military artist that applied for entrance into the CFAP.⁶ She had to document every ailment that she has incurred, and every doctor that she has visited in the last ten years. With having multiple sclerosis (MS), she's had more paperwork to fill out than any other applicant. Along with having MS, she also has motion sickness and had to contact The Department of National Defence (DND) and talk to her contact about her condition in order to be approved to go.

After the tedious process she had to endure to prepare for Afghanistan, she found out that she was to do her study at the Canadian Forces Medical Services (CFMS) with the medical personnel at Role 3 Medical Unit, which is a *Triage* hospital at Kandahar Air Field (KAF), twenty-four kilometres outside Kandahar. The location that Bailey was situated at no longer exists. Bailey left for her trip to Kandahar on Friday June 22, 2007, which was the beginning of the short period of time she had to capture what happened at the Role 3 Hospital.⁷ She flew from Trenton, Ontario to Kandahar, Afghanistan with the Canadian Forces, flying through Brize Norton in England then to Budapest and Dubai. During the flight out Bailey recalls:

When the troops were ordered to prepare their weapons, one soldier turned to ask me: 'Where's your weapon?' I pulled a pencil from my pocket and, holding it high, declared: 'The pen is mightier than the sword.' He responded with a blank stare, then turned to ready his weapon.⁸

I found this particular quote very intriguing. The pen, to Bailey, is more powerful than anything else. With a pen, she can create anything and with a sword, one can only kill. To keep herself distracted on the flight, Bailey sketched the soldiers dozing off. She ended up arriving on Monday June, 25, 2007, a day early, due to miscommunication and was given a lift by a passenger to the administration office.

Bailey documented what was happening at the Canadian Forces Medical Service (CFMS) at the Role 3 Military Medical Unit in Kandahar by sketching and photographing what she saw there, as well as keeping a diary of her experience. Bailey "captures the small gestures, the brief glance and the unexpected detail in the ordinary scene to create remarkably intimate views of her exposure to Canadian military experience in Afghanistan."⁹ When Bailey arrived she went straight to sketching patients at the medical unit. Some of Bailey's work reflects more than people. For example, everyday, one of the hospital staff was assigned to pick up coffee and doughnuts at Tim Hortons.

The Tim Hortons provided a great source of comfort and a small reminder of home to the nurses and doctors that were assigned to the Unit. Bailey documented this experience by painting "Tim Hortons I", "Tim Hortons II" and "Lineup at Tim Hortons".

Everyone thinks that her "Self-Portrait on Hercules 1" painting is a portrait of a soldier from Kandahar. Very few at first realize that it is actually a self portrait of Bailey. She felt it was important that she be represented in a military situation, "[she] painted the workers and the artist is a worker too."10 She explained that self portraitures have been a visual diary for her throughout the years, which can be seen in other projects that she has done. "Self-Portrait on Hercules 1" was chosen as one of the pieces to be exhibited at "A Brush with War - Military Art from 1946. "Self-Portrait on Hercules 1" appeared on invitations, posters, catalogue covers and the entrance display.¹¹ Bailey stated that she was very happy that her piece was selected for this use.

What Bailey didn't talk about for a period following her brush with war is how nervous and jetlagged she was at the time, nor did she mention how intimidated she felt at first, around the many men suffering head injuries, and how she was drawn towards a



Karen Bailey, Sketch of Maztlifa, 2007, Kandahar



Karen Bailey, 2008-2009, Kandahar

girl in a tiny wheelchair with a leg injury, who was her first subject. Maztlifa the injured eight-year-old girl ,who was the first patient that Bailey sketched. She was injured as a result of a Taliban attack on her family that ended up with her father being killed and her body being covered in wounds. "While I sketched she gazed at me intently from her tiny wheelchair, legs encased in dressing."¹² Bailey says that "a girl in a tiny wheelchair with a leg injury was less intimidating to sketch than an adult male with severe head injuries."¹³ Maztlifa was the only female patient during the time Bailey was there. Bailey thinks that she "provided [Maztlifa] with a temporary distraction from the tedium of hospital life."¹⁴

Most typically Bailey has been painting with acrylic and using a limited, "high-key", palette, consisting of alizarin crimson, ultramarine blue, and cadmium over a burnt sienna base. For her military work, she employed a limited, "low-key", palette with napthol red light, paynes grey and yellow ochre over the burnt sienna base. There is something more sombre about this grouping of colours that is in it keeping with the colours of camouflage. Bailey favoured using a very limited palette, which consisted of very limited colours of paint, occasionally alone accompanied by the occasional spot of cadmium red or naples yellow would be used. "A limited palette keeps unity in my work and with three colours one can create a complete spectrum."¹⁵

The photographs and sketches that Bailey did while she was at the Role 3 Military Medical Unit later became studies for paintings after she returned to Canada. As she began to work on these paintings, she ended up changing the layout of the original sketches. Bailey's painting "Blast Victim" is one of the paintings that went through changes. Originally Bailey painted a male nurse in the background, but in the final piece he is removed it and focuses on the Lt. (N) Tobi Dwyer who was the nurse that was cleaning the tracheotomy of the "Blast Victim" patient.¹⁶ In 2011 "Blast Victim" was included in the War and Medicine Exhibition at the Canadian War Museum.¹⁷

Bailey is one of a select few that have been given the opportunity to become part of the Canadian Forces Artist Program (CFAP) to document in writing, photography or sketching. Bailey captured individuals on the back line, which is seen in her book *Triage* work, which took Bailey two years to create. Given Bailey's experiences in Kandahar she has a lot to offer about living on the edge of conflict. What draws people to her is the medium she chose to show it in, and the eyes she saw it through. She wasn't seeking the battle, she sought the efforts of people to live, heal and rebuild. *"Triage* presents one week in the Role 3 Hospital at Kandahar Air Field, a week filled with commitment and compassion."¹⁸

Endnotes

¹ The Canadian Encyclopedia, War Artist, 2013

²National Defence and the Canadian Forces, CFAP Historical Background, 2013

³National Defence and the Canadian Forces, CFAP Historical Background, 2013

⁴National Defence and the Canadian Forces, CFAP Historical Background, 2013

⁵Karen Bailey, Triage, Ontario: Red Setter Publishing, 13, 2010

⁶Karen Bailey, 13

7 Karen Bailey, 13

- ⁸ Karen Bailey, 11
- ⁵ Email
- °Email
- ⁷Karen Bailey, 19
- ⁸Email
- ۶Email
- 10 Email
- ¹¹ Dictionary
- 12 Email
- ¹³ Email
- ¹⁸ Karen Bailey, Triage, Ontario: Red Setter Publishing, 24, 2010

References

Canadian Encyclopedia, War Artist, http://www.thecanadianencyclopedia.com/articles/ war-artists, 2013

Karen Bailey, Triage, Ontario: Red Setter Publishing, 2010

Karen Bailey, Karen Bailey, http://www.karenbailey.ca/, 2013

National Defence and the Canadian Forces, CFAP Historical Background, http://www. cmp-cpm.forces.gc.ca/dhh-dhp/gal/ap-pa/cfap-pafc-eng.asp, 2013

National Defence and the Canadian Forces, CFAP Selected Artists 2005-2007, http://www. cmp-cpm.forces.gc.ca/dhh-dhp/gal/ap-pa/sa-as-0507/index-eng.asp , 2013

Interview with Karen Bailey, Canadian Forces Artist Program, E-mails, Oct 2, 2010 -April 3, 2012

Oxford Paperback Dictionary and Thesaurus, New York: Oxford University Press, 2009, p.982.

An Overview of the Great Expulsion, Subsequent Migrations and Acadian Cultural Persistence

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Abstract

This research essay provides an overview of the historical context preceding the Great Expulsion which took place in 1755, as well as the resulting Acadian population movements and their impact on the surrounding landscape. The military justification for the Great Expulsion, the reaction of the American colonies towards the newly arrived Acadians, and the aftermath of the Seven Years War are all touched upon in order to provide a clear chronological narrative. This has been done by compiling and synthesizing information from a variety of sources. The development of the Acadian culture from its inception to the present-day is an integral part of Canadian history. The purpose of this paper is to present the survival of the Acadian culture through a very tumultuous and crucial time in Canadian history.

Introduction

Since the start of the European expansion into the New World, Canada was a point of contention between two world powers at the time, England and France. The Acadians were one of the many cultural groups affected by the series of conflicts between the two empires. However, the Acadians are notable since despite their French origins, they did not regard themselves as being part of New France. This can be attributed to the geographical isolation of their land, Acadia. It encompassed most of the modern day Maritimes, and was put aside after the more profitable discovery of the St Lawrence passageway. For this reason, it became less of a priority for the French. Thus, the Acadian culture was permitted to develop, free from the external administrative influences of the old continent. This research essay aims to provide an overview of the historical context preceding the Great Expulsion which took place in 1755, as well as the resulting Acadian population movements and their impact on the surrounding landscape. The military justification for the Great Expulsion, the reaction of the American colonies towards the newly arrived Acadians, and the aftermath of the Seven Years War are all examined in order to provide a clear chronological narrative which presents the survival of the Acadian culture through a very tumultuous and crucial time in Canadian history.

The Great Expulsion

Acadia had changed hands on multiple occasions prior to the establishment of the Treaty of Utrecht in 1713. Yet this treaty is significant, since France was forced to permanently cede all claims to Acadia, which the British quickly renamed Nova Scotia. However, despite giving up the mainland, France retained control of the islands surrounding it.¹ They immediately began to shore up their defences, as can be seen with the founding of Fort Louisbourg on Ile Royale in 1719. This permitted them to solidify their grasp on the entry of the St Lawrence River and retain a position of influence in the area.² As the British began to settle in their newly conquered territories, they faced opposition from the three cultural groups already present; the Mi'kmaq, the French and the Acadians.

One would be remiss to ignore the importance of Fort Louisbourg in regards to the development of the events leading up to the Great Expulsion. The reasons for building the French fort can be seen as being initially defensive. Its purpose was to protect Quebec city and the rest of New France from British attack, by controlling access to the St Lawrence river.³ However, during King George's war, it began to take on an increasingly

offensive role in military operations. The attacks carried out by the French from Fort Louisbourg include the battle for Fort St Anne and the multiple sieges of Annapolis Royal, previously known as Port Royal.⁴ The threat of Fort Louisbourg was successfully eliminated in 1745. However, the Treaty of Aixla-Chapelle in 1748 returned it to the French, to the dismay and anger of the British military present on location.⁵ Since Fort Louisbourg had proved to be a threat, and had just been returned to the enemy, the need to prevent Acadia from falling back into French hands became one of the main concerns of the British government. Thus began a series of conflicts which became known as Father Le Loutre's War.

Starting in 1749, the British began building a series of forts in an attempt to reduce the French threat. Unfortunately, this created new, unforeseen conflicts: when General Edward Cornwallis landed on the shores of Chebucto and began building Fort George, situated in present day Halifax, he violated earlier treaties that had been established in the aftermath of previous conflicts between the British and the indigenous Mi'kmaq.6 The Mi'kmaq quickly made their disapproval known by mounting a series of attacks on British held territory. These attacks became increasingly violent, leading to British retaliation, which resulted in an escalating amount of casualties on both sides. The French saw this as an opportunity and began infiltrating both the Acadian and Mi'kmaq population, encouraging and inciting them to join their cause.7 Acadian rebel leaders such as Joseph Broussard, better known as Beausoleil, started to openly criticize and attack their conquerors.8 These violent raids provided the British with an even greater impetus for a strong military stance. The fact that many Acadians took part in these attacks complicated their relationship with the British authority.9 While the rebels may or may not have spoken for the Acadian population as a whole, these attacks, along with the fact that the Acadians' claim of neutrality had always been doubted by the British authority, led Lieutenant-Governor Charles Lawrence to conclude, at the onset of the Seven Years' War, that exiling the Acadians was the only way to ensure that Nova Scotia would not fall once more into French hands.¹⁰

From a purely military standpoint, it seems that Lawrence was justified: in the aftermath of the Great Expulsion, Nova Scotia continued to grow in military importance throughout the Seven Years War, culminating when one of its forts, Fort George, was used as the launching point for the second siege of Fort Louisbourg in 1758.¹¹ An important battle in its own right, this particular victory can be regarded as the turning point in the Seven Years War. At the time, the strength of a country's navy directly affected its chances of victory. Not only were ships powerful weapons with their cannons, they were also efficient means of transport; channeling troops and supplies quickly from port to port, as John Grenier states: "The key to the French campaign in Acadia depended on the navy's ability to supply the army."¹²

The fall of Fort Louisbourg underlines this important notion; England now had full control over the coastline. With the loss of their fort, New France was cut off from their source of finances and man power.¹³ It is also important to note that the British used Louisbourg as a launching point for their naval attacks on Quebec.¹⁴ This culminated in the Battle of the Plains of Abraham in 1759, in other words, the fall of New France. This in turn led to France relinquishing all claims to Canada at the end of the Seven Years War, with the exception of the two islands, Saint Pierre et Miquelon.¹⁵ To attack New France, Fort Louisbourg needed to be conquered. For this to occur, the British needed to cement their claim on Nova Scotia, a feat they accomplished by deporting the majority of the Acadian population.

The Aftermath

The Great Expulsion can be regarded as being comprised of two separate deportations which occurred in 1755 and 1758. For the purpose of this paper, we will be focusing on the first, which resulted in over 7000 Acadians being scattered among the Thirteen colonies.¹⁶ Many historians have recorded the deficiencies of the British government in regards to the treatment of the Acadian people. The general consensus is that the Expulsion was badly planned, and that the living conditions were atrocious. As a result, entire families were separated, and many died due to starvation and sickness.¹⁷ While these facts may be excused due to the time constraints surrounding the Expulsion and the fact that this event occurred during a period of wartime, the treatment the Acadians received once they arrived to their assigned destinations could not be dismissed using the same rationale.

Despite not having enough resources to accommodate the newly arrived Acadians, a few colonies, Maryland and Connecticut in particular, made efforts to welcome them by giving them shelter and in the case of the latter, making provisions for them in their legislature: "[they were to] be made welcome, helped and settled under the most advantageous conditions, or if they have to be sent away, measures be taken for their transfer."¹⁸ Unfortunately, this was not characteristic of the way the Acadians were welcomed in the other colonies. Acadians sent to Massachusetts were forced to stay in the harbour for three months during the winter time. As a result of William Shirley's orders, approximately half of them died due to freezing temperatures and malnutrition.¹⁹ Once they were actually allowed to debark, many children

were taken away from the remnants of the family they had and distributed to American families.²⁰

The authorities in Virginia, refused outright to accept Acadians. They were eventually sent to England where they were held as prisoners of war until the Treaty of Paris in 1763.²¹ There are also reports that many Acadians sent to South Carolina, North Carolina and Georgia were forced to work on plantations.²² These facts point to the conclusion that the Acadians were regarded as being burdens on the American colonies. Thus, it is not surprising that the resources available to them were very limited. As outlined above, in many cases they were greeted with hostility and contempt. However, it was thought by the British government that the Acadian threat had been successfully neutralized since they would eventually assimilate and thus become Americans -- this however, proved to not be the case.²³ Also very telling is the fact that during the second expulsion, the Acadians were sent directly to England.²⁴ While it is only pure speculation, it is possible that the British government, realizing that the American colonies were not willing to welcome new French-speaking individuals of a different faith into their communities, decided to search for other alternatives. One such alternative would have been sending them back to their home country, a place they knew little of and had only heard about from old family stories passed down from generation to generation.

With the end of the Seven Years Wars in 1763, the Acadians were once again free to travel. This is significant because the following migrations were the ones instigated by the Acadians themselves. Many returned to France in the late 1770s.²⁵ However, once they arrived, they now faced a difficult situation; in the same manner the Acadians had always regarded themselves as being separate from the citizens in New France, they did not identify as being French. This can be attributed to the fact that the Acadian identity had evolved in a different direction than that of their French counterparts. Language was now the only thing they shared. Their customs and cultures were no longer interchangeable with each other. For this reason, a significant percentage chose to return and settle in the new world; out of the approximate 5000 Acadians who made their way to France, more than half left it within one generation.²⁶ Instead of culturally assimilating and thus vanishing, they built themselves new homelands, the two largest of these new settlement, are present-day Louisiana and New Brunswick which still pride themselves on their Acadian heritage.

Due to its origin as a French colony, Louisiana seemed like one the best alternative for many Acadians. It already had a strong French speaking population and by 1764 it was firmly controlled by the Spanish after the terms of the Treaty of Fontainebleau were revealed; thus it was out of British control.²⁷ The years passed, and the Acadians became part of the existing Creoles population, yet they still retained remnants of their Acadian identity; note the evolution from *Acadian* to *Cadian* to the present day term *Cajun*. As the name used to describe them changed, so did their culture; the present day Cajun culture may initially seem to be entirely separate from its Acadian origin. However, this can be attributed to the fact that all cultures evolve, merge and sometimes even disappear. What is notable about the Acadians in Louisiana is that while their modern day cultural presence may be disputed, their geographical impact cannot be: some of the territories they initially settled in are now defined as Acadiana, thus referring directly to its origin.

The Acadians who returned to their homelands faced a much harder path. The newly appointed governor, Michael Francklin, gave them guarantees to encourage their return: Not only would they have the right to practice their Catholic faith, he also issued a promise that there would be no more attempts to exile them.²⁸ However, upon their arrival, the Acadians found that their previously fertile farmlands were either destroyed and neglected, or given to newly arrived British and New England settlers. Quickly recognizing that any attempt to regain their land would be futile, they began to search for different alternatives. At the time, present day New Brunswick was mostly uninhabited since the British preferred to establish themselves along known territory in the maritimes.²⁹ Among other reasons this is the essential reason that led to the British government's decision to allow the Acadians' settlements to continue. Due to the terrain, which was not well suited to agriculture, and the harsh living conditions the Acadians chose to settle along the coast.³⁰ To survive, they were forced reduce their reliance on farming and develop other means to fulfill their financial needs. Initially the fishing industry fulfilled that need. Later, the rise of European demand for lumber, due to the start of the Napoleonic wars which cut England off from their traditional supply sources, sustained it.³¹ Instead of culturally assimilating and thus vanishing, the Acadians found new homelands, finding ways to flourish despite adversity.

To further illustrate this point, the growth of the Acadian population during this time frame should also be examined. In 1763 at the end of the Seven Years' War, less than eight years after the first expulsion, the Acadians were scattered throughout the Thirteen colonies. However, forty years later, they had congregated in regions and begun re-establishing themselves in their former territories. The Acadian population in Louisiana grew by more than ten-fold. Their presence in Quebec more than quadrupled, while the Maritimes also showed a similar increase in population. Most telling is the fact that the total population had doubled, indicating that despite their hardships, the Acadians had successfully ensured that their customs would be passed on to the next generation.³²

Conclusion

Throughout Canadian history, many cultural groups suffered as a result of the various conflicts. Yet the Acadians are notable since despite their French origins, they had developed into their own culture. Since the Acadians was permitted to develop, free from the external administrative influences of the old continent, the result was a culturally independent population that had little concern for the larger-scale struggle of gaining control over territory. In many ways, The Great Expulsion can be defined as an event that both destroyed and created a culture. While ancestral lands and ways of life were irrevocably lost, instead of assimilating into their surroundings many Acadians retained their values and adapted to their surroundings as indicated by the renewal of Acadian culture that can be observed in the present-day Maritimes and Louisiana.

When it comes to representing a culture's identity, perhaps no other symbol can accomplish this purpose as well as a flag. Hence, the Acadian flag which was designed and introduced in 1884 at the Second Annual Acadian National Convention becomes paramount to the Acadian culture. More than a hundred years after the Great Expulsion, the Acadian identity was for the first time represented by its own flag.³³ The words of Father Richard, the man who created it, clearly underline its significance:

"I wish that Acadia has a flag reminding not only that its children are French, but also that they are Acadians" $^{\rm 734}$

This pride in the Acadian cultural heritage was once more shown with the creation of the Acadiana flag in 1965, which was meant to represent the Acadian heritage in Louisiana.³⁵ It is a testament to the strength and resilience of the Acadian people, and their culture that even now, the need to identify oneself as Acadian is so prevalent.

Endnotes

- ¹ John Stewart McLennan, *Louisbourg, from its foundation to its fall, 1713-1758,* (London, 1918) 58-59.
- ² Walter R Borneman, *The French and Indian War: deciding the fate of North America*, (New York, 2006) 8.
- ³ Cole R. Harris and Geoffrey J. Matthews, "The Seven Years' War," in: *Historical Atlas of Canada, From the Beginning to 1800,* (Toronto 1987) Plate 42.
- ⁴ Grenier, *The far reaches of empire*, 109-115.
- ⁵ John Stewart McLennan, *Louisbourg, from its foundation to its fall, 1713-1758*, (London, 1918) 181.
- ⁶ Grenier, *The far reaches of empire*, 71.
- ⁷ Grenier, *The far reaches of empire*, 148.
- ⁸ Grenier, *The far reaches of empire*, 150, 160.
- ⁹ Peter Ward, "The Acadian Response To The Growth Of British Power In Nova Scotia, 1749-1755," Dalhousie Review 51 (1971): 175.
- ¹⁰ Steven G. Greiert, "The Earl of Halifax and the Settlement of Nova Scotia, 1749-1753," Nova Scotia Historical Review 1 (1981): 22.
- ¹¹ Harris, "The Seven Years' War," in: *Historical Atlas of Canada*, Plate 42.
- ¹² Grenier, *The far reaches of empire*, 119.
- ¹³ Frank W. Brecher, Losing a Continent: France's North American policy, 1753-1763, (Westport, 1998) 135-136.
- ¹⁴ Harris, "The Seven Years' War," in: Historical Atlas of Canada, Plate 42.
- ¹⁵ Brecher, Losing a Continent, 153.
- ¹⁶ Cole R. Harris and Geoffrey J. Matthews, "Acadian Deportation And Return," in: *Historical Atlas of Canada, From the Beginning to 1800*, (Toronto 1987) Plate 30.
- ¹⁷ Naomi E.S Griffiths, From Migrant to Acadian, (Montreal, 2005) 438.
- ¹⁸ Bona Arsenault, *Histoire des Acadiens*, (Quebec, 2004) 153.
- ¹⁹ Fintan O'Toole, White Savage, William Johnson and the Invention of America, (New York, 2005) 154.
- ²⁰ Arsenault, *Histoire des Acadiens*, 197.
- ²¹ Arsenault, *Histoire des Acadiens*, 203.
- ²² John Mack Farragher, A great and noble scheme: the tragic story of the expulsion of the French Acadians from their American Homeland. (New York, 2005) 353.
- ²³ Geoffrey Gilbert Plank, An Unsettled Conquest: the British Campaign Against the Peoples of Acadia. (Philadelphia, 2001) 70.
- ²⁴ Cole R. Harris and Geoffrey J. Matthews, "Acadian War and Return," in: *Historical Atlas of Canada, From the Beginning to 1800,* (Toronto 1987) Plate 30.
- ²⁵ Harris, "Acadian War and Return," Plate 30.
- ²⁶ Harris, "Acadian War and Return," Plate 30.
- ²⁷ "Notre Dame Archives: Louisiana." Notre Dame Archives. http://archives.nd.edu/mano/ louisian.htm (accessed November 20, 2011).

- ²⁸ "FRANCKLIN, MICHAEL Dictionary of Canadian Biography Online." http://www. biographi.ca/009004-119.01-e.php?&id_nbr=1892 (accessed November 25, 2011).
- ²⁹ Cole R. Harris and Geoffrey J. Matthews, "Loyalist Settlements" in: *Historical Atlas of Canada, From the Beginning to 1800*, (Toronto 1987) Plate 32.
- ³⁰ Harris, "Acadian War and Return," Plate 30.
- ³¹ William Stewart MacNutt, "The Politics of the Timber Trade in Colonial New Brunswick, 1825–40." Canadian Historical Review, 30 (1949): 63.
- ³² Harris, "Acadian War and Return," Plate 30.
- ³³ Perry Biddiscombe, "Le tricolore et l'étoile; The Origin of the Acadian National Flag, 1867–1912." Acadiensis 20 (1990): 120.
- ³⁴ Biddiscombe *The Origin of the Acadian National Flag*, 124.
- ³⁵ Shane K. Bernard, The Cajuns: Americanization of a people. (Jackson 2003) 167.

Does Convergence Theory Help to Explain Resiliency after Land Reform in Mexican *Ejidos?*

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Abstract

Since 1917 as much as half of Mexico's land base has been dominated by state-led communal agricultural lands called ejidos. However, relatively recently, major land reforms have taken place. Starting in 1992-93 laws were passed prohibiting the expansion of common state-run land and allowing the privatization of ejido land. In 1995 Mexico joined the North American Free Trade Agreement (NAFTA), which requires the government to gradually take away all price guarantees, protective tariffs, and barriers on staples like corn and beans. In addition Mexico is required to open up its economy to foreign investment and export markets. This is causing in some ejido lands a decline in income and / or an increased instability of employment for ejido residents.

The theory of convergence states that when a regional economy's needs converge with the goods and services it is producing, a more stable and resilient economy results; an economy that is less prone to macro economic changes in the global economy. The theory of convergence economics comes from Clive Thomas (1974) who studied the effects of convergence in the economy particularly related to food and the agricultural crops in Tanzania in the 1970s. During these years, almost ten years after Tanzanian independence the government was pursuing policies that share some resemblance to current Mexican economic policies. Policies that aim to increase the production of export crops, and market openness. Using case studies from three ejidos, this paper addresses the question of whether the level of ejido community resiliency through the land reforms have corresponded to some form of convergence in their agricultural production and consumption.

Introduction

In many parts of the world communal lands exist and predominate over land resources. Countries such as China, Vietnam, most parts of Africa, and many countries in Latin America have political and social structures for land set aside for communal agriculture (Deininger and Bresciani, 2001). Ejidos originated in Mexico with the 1917 constitution after the Mexican revolution. Ejidos are state-led agricultural lands that have been farmed communally. Traditionally, those who farmed the land, the ejiditarios, never held title to these lands but rather had usufruct rights that allowed the use of water and terrain. The federal government reports "29,000 ejidos, with 3.5 million ejidatarios" that covers half of national territory (Haenn, 2006: 137). Three million households, more than half the rural population of Mexico lives on the 100 million hectares of ejido land (Deininger and Bresciani, 2001: 2). Ejidos, which were initially implemented to model precolonial indigenous social structures, are found in all parts of Mexico and make up 50% of the total available arable land (ibid.). The governing power in ejidos is shared among stakeholders, along with the land. In ejidos, agrarian or forest based livelihoods are customary and resources in the community are usually distributed relatively equally (Barnes, 2009).

Convergence in ejidos means the production of crops, aquaculture, and other goods being produced within the community that consumes them. Although a shift away from this model can bring benefits to many communities, convergence theory is based on studying impoverished areas of the world, and factors such as ease of access to food, shelter, health care and other basics used as metrics for the relative well being of a community instead of traditional economic metrics such as Gross Domestic Product. By measuring resilience it could be interpreted that the goal of ejido communities is to remain the same, or resist change. This study is not commenting on the overall goals of ejidarios or the ejido community in Mexico at large. However, measuring resilience is pertinent because ejidarios did not choose these land reform changes nor vote NAFTA nor any other international trade policy that forces them from their homes because they are no longer able to make money from farming tradition staples nor other types of goods. Ultimately this study aims to ascertain whether ejidarios who would like to choose to live in these communal agrarian settings as they did before the land reforms are indeed able to.

I chose case studies based on the available case studies of ejidos in the literature. There were two factors that influenced the choice of ejido to be used as a case study. First, in the literature review I looked for articles that followed

an ejido or group of ejidos over a time period that spanned the land reforms. Second, I looked for articles that contained qualitative information such as employment availability within the ejido, worker commute times to outside jobs, and whether ejidarios are earning incomes at numerous seasonal jobs or simply at one place of employment. I was looking for case studies that gave more quantitative information on whether the form and structure of the ejidos (as resilience is defined below) remained the same after the PROCEDE land reforms and the trade policies in NAFTA.

Purpose

The purpose of this paper is to use case studies from three ejidos to addresses the question of whether ejido communities that have maintained resiliency through the land reforms have practiced some form of convergence in their agricultural production and consumption. Similar to the results Clive Thomas found in Tanzania, in these impoverished areas, it appears that corporate ownership of land and control over the production of crops (destined for export) does seem to inhibit access to basic needs, and stable income in the ejidos in the case study, resulting in population loss, long commuted for those who stay and a loss of access to the once communal land.

Land reforms in Mexico

The official ending of ejidos as communal state-led agricultural land was in 1992. The ejido system had been criticized for three main reasons leading to this change. First, because ejidos were thought to hinder land access to young people in rural areas; fifty three percent of ejidarios are older than 50 (Deininger and Bresciani, 2001: 2). Second, ejidos can be seen as an obstacle to urban expansion when located next to burgeoning city centers, and finally, they are charactarized by low levels of "capital investment" (ibid.). With the PROCEDE program (Programa Nacional de Certificacion de Derechos Ejidales y Solares Urbanos or Program for the Certification of Ejido Land Rights and the Titling of Urban House Lots), there were several other changes to the Mexican political system that drastically altered the facility of farming and the livelihoods of the ejidarios. These shocks started with a serious pull back of support for Mexican farmers in the debt crisis during the 1980's (Parramond, 2008). The government enacted the PROCEDE program following the debt crisis in 1992. PROCEDE allowed the mapping of historic land use patterns and the privatization of land to the ejiditarios that farmed it (Parramond, 2008; Barnes 2009). The PROCEDE program also greatly increased the limits on maximum allowable owned land for corporations. Previously individuals

or corporations did not have the right to farm over 100 hectares of land, and while this is still the case with individuals, corporations have the right to purchase twenty five times that historic maximum (Bonnis & Legg, 1997).

Shortly after the PROCEDE program implementation, Mexico signed the North American Free Trade Agreement (NAFTA), the first free trade agreement between developed and developing nations to include agriculture (Bonnis & Legg, 1997). NAFTA required the total elimination of agricultural subsidies to farmers in ejidos, as well as the eradication of tariffs and barriers for trade with the United States and Canada by 2008 (Barnes, 2009; Bonnis & Legg, 1997). NAFTA caused an aggregate shift to the production of export fruits and vegetable, reducing crops for local consumption (Getz, 2008). This affected farmers who relied on set prices for staples such as corn and beans. Another program called Procampo, was initiated to give direct payments to land holding farmers, because of the reduction of the price supports (Bonnis & Legg, 1997). However, after the removal of the trade tariffs in 2008, the market was flooded (even regarded as "dumped on") with much cheaper corn and beans from the rest of North America, particularly from the Unites States, and many Mexican farmers in ejidos could no longer make a living producing these crops (Jacinto, 2008). This has been demonstrated numerous times by protesting farmers who oppose the restrictions for government support of farmers and barriers to trade (BBC, 2012 Jan 23).

In the literature, the primary driver of change in Mexican ejidos is usually attributed more to the signing of NAFTA than the PROCEDE program. This is because the process for a consensus decision on how to privatize the land, and even whether to privatize the land is rare in ejidos. Research from the late 1990s suggests that only 2% of ejidos has indeed taken advantage of the opportunity to privatize (Haenn, 2006). However, this number is likely increasing, especially in areas where demand for land is high. Mexican farmers on ejidos in areas near cities experience the effects of urbanization, particularly the rising prices of land around these areas. In some areas, including popular tourist destinations, this places a lot of pressure on the ejidos because the land prices were so high (Barnes, 2009).

In summary, by 1992 ejidos were largely deemed uneconomic by government and policy makers. Starting with the supports pulled out from farmers during the debt crisis in the 1980s, then the allowance of corporate ownership of large tracts of ejido land due to PROCEDE in 1992, and finally the removal of all trade tariffs and barriers due to NAFTA in 1995, traditional ejidarios farming on communal land drastically changes and largely became less viable financially.

Convergence theory

As mentioned in the introduction, convergence theory is the notion that by bringing together the production capacity of a community and the needs of that community, a better quality of life can be achieved in impoverished places (Thomas, 1974). Conversely, divergence is the process by which local crops and ownership of land moves away from locally consumable products and is characterized by heavy capital investment and large-scale goods for exports. In Tanzania and Mexico, a social structure existed where many local staples were once grown and consumed in the same regional economy. In Mexico, traditional corn, beans and other vegetables like squash were commonly grown for local consumption or at least for domestic consumption. Trade barriers and tariffs helped protect the price of goods grown locally, so farmers were incentivized to continue to produce goods that met the demands of the local population. The simple but profound theory that resiliency is greater when economic supply and demand converge has been largely overshadowed globally by government policies that encourage foreign investment and export market development to improve prosperity. Thomas (1974) argues that although GDP may increase with the rise of deregulated and large-scale global trade, the inequality of poor countries often increases too, and education, health care and basic nutrition become harder to obtain for a large percentage of the population (Thomas, 1974). The reason I chose to look at this development theory in particular was the link between postcolonial Tanzanian policies and the types of policies the Mexican government has implemented since signing NAFTA in 1995. In both cases the governments are inviting foreign interests to purchase land, invest capital and produce for the export market. Both countries experienced a variety of shocks over a number of years that destabilized their traditional land use. Finally, the populations of rural farmers in both Tanzania in the 1970s and Mexico more recently struggled with export market policies. In Tanzania, Thomas (1974) describes the difficulties as pertaining to the growing competition and high elasticity of demand in the global market for the export crops that were grown and produced in Tanzania. In Mexico, it is difficult for an ejiditario who loses the ability to support his family through farming, to earn a similar standard of living through seasonal employment with a large export oriented farm.

Resilience

In Clive Thomas's book, he describes the success of programs to encourage convergence in the Unjamaa village in Tanzania. This community was experiencing difficultly with policies that encourage land and labour to be directed to the export market. Thomas suggests methods for converging supply and demand to help Unjamaa hold on to its structure and function. This is part of the definition of resiliency: "Resilient systems are able to absorb shocks and adapt themselves without changing their fundamental structure and function" (Barnes, 2009: 393).

In this paper, I will look at whether elements of convergence found in case studies of Mexican ejidos increase the resilience of the ejido. I will look at instances where production and consumption converge, as well as the inverse divergence, which Thomas describes as: "rooted in such basic structural relationships as foreign ownership and control of domestic resources, export specialization for metropolitan markets, the pervasiveness of foreign decision making over domestic economic processes" (p.123). I will assess, based on the three case studies on Ejidos where components of convergence and divergence are present what sort of effect it had on the needs of the local community being met.





Case study: El Cerro, Sinaloa

In El Cerro, a fairly new ejido (established in the 1970s), there is a fairly high concentration of commercial agriculture that provides seasonal employment for ejidarios. The primary crops are chili, mangoes and broomcorn for export. This represents the main divergent economic factor in the community. There is also a shrimp export industry in the area, which employs six local residents. An element of divergence can be found in the fishing industry. Most of the men in El Cerro fish all year round, a steadier source of income; they sell the fish to local restaurants and catch crab for their own consumption. This was the main food production in the area. Poor soil quality prevents El Cerro from being able to grow crops without investment of some kind of fertilizer input. Cruz-Torres (2004) also noted there were several non-ejidarios members of the community, and that these people were far poorer than their land owning counter-parts.

El Cerro is a good example of resiliency in an ejido that displays signs of convergence. The main industry, seafood harvesting provides steady yearlong income to its workers, and the harvest is going to local restaurants for consumption. The non-ejidarios members of the community who experienced increased poverty exemplify one of the criticisms of the ejido system, that they make access to land more difficult for those who live in rural areas outside of ejidos. Ultimately, they are not privy to the benefits of the convergence of El Cerro's economy without land or water rights to produce food for consumption. The next case study shows that when the regional economic trends are more divergent, it can result in many ejidarios living in extreme poverty, and giving up access to their land through leasing agreements.

Case Study: Coastal Sonora Ejidos

In this 2006 study Luers, Naylor, & Matson looked at a group of 41 coastal ejidos in close proximity on the coast of Sonora. Many of these ejidos reacted in a similar way to the various land reform shocks, so it is useful to look at them as a group to assess convergent and divergent trends. Particularly after NAFTA was signed and the related policies implemented, there was widespread engagement in commercial shrimp farming. The biggest change since the land reforms has been the ownership of shrimp farms. In 1990s 70% of ejiditarios owned shrimp farms, in 2006 only 30% of this same group owned the farms, and the other 70% were still involved through renting the space to other commercial shrimp farm companies. The shrimp farming has been a difficult process for the ejiditarios, and many of the farms actually operate at a loss. According to Luers, Naylor and Matson's (2006) over 70% of the ejiditarios

lose money in shrimp farming. The factors for these losses are two fold. First, there have been many unfavorable storms that have badly damaged the infrastructure for the shrimp farms, and second, disease and other environmental problems in the ecosystem have badly affected the shrimp and made it difficult for farmers to earn wages. There seemed to be very little in the way of local consumption of these shrimp in the case study, and little other economic activity that would service the community itself. This case study highlights what impact large-scale foreign owned farms can have on the environment, as well as the economic well being of an area. Not confusing correlation with causation, it is not possible without an in depth analysis of the particular environmental problems to determine if this decline in shrimp farms was indeed due to overcrowding, or too large a scale of production. However, because little of the food was produced for local consumption, when shrimp production ceased to be active, many were left unemployed with no income nor other means of obtaining food. This is an example of divergence. The theory of divergence and convergence pertains primarily to impoverished areas and basic needs such as food and shelter. Although the capital investment of foreign owned companies may eventually benefit the GDP in Mexico as a whole, during low periods such as in the costal Sonora ejidos, many workers now dependent on income to purchase food are left unemployed and with no immediate security. Resilience here is low, as this forced ejidarios off the land, to look for work in cities, factories, and tourist areas. Although this in and of itself is not an intrinsically bad outcome, the resiliency of the ejido to maintain its form and function is almost completely diminished. Those who would choose to stay on the ejido no longer have the choice.

Case Study: Yaxbe, Yucatan

Hull (2007) studied an ejido on the east coast of Mexico, in an area that is an extremely popular tourism destination, as well the site of major Mayan ruins and historical settlement. She found that the collapse of tradition markets due to the land reforms in this community resulted in three major changes: (1) a diversified family income where female wage earnings has doubled, (2) long commuting long distances for workers from Yaxbe, and (3) the out migration of many people, especially young people. Hull found that it was quite easy for work in the nearby tourist resorts. Some men succeeded in finding work in heavy industry and heavy manufacturing, but overall, the land reforms in this ejido affected middle-aged men the most. There is some vegetable

farming but again the soil quality in the region is a barrier for producing food for local consumption. In this case study we see that foreign interests in the tourist sector draw people away from the ejidos and manufacturing export product wages are very low. Unfortunately, there is little opportunity to produce food and goods in the community that will be consumed by the community, as the market failures have resulted in in the impracticality of traditional farming crops.

Discussion

On a nation wide level the debt crisis, PROCEDE land reforms and policies related to NAFTA have resulted in increased poverty in the rural sector, an increase in income inequality in ejidos and a decrease an actual numbers employment in agriculture (Getz, 2008; Jacinto, 2008). In the description of the main characteristics of ejidos Barnes (2009) cites communal and participatory government, livelihood strategies based on agriculture or forestry (or aquaculture) and finally the equitable distribution of resources in an ejido as the main aspects. In the case studies it seems that these fundamental elements of ejidos have eroded in many ways, and in some cases convergence did help prevent this erosion. Convergence of demands and local supply in the example of fishing in El Cerro support convergence theory because the economic activities that were aimed for local consumption provided yearround employment whereas the commercial farming only afforded locals seasonal jobs. In El Cerro and Yaxbe, the soil quality was a barrier to local food production of vegetables, making efforts for convergence difficult. However, while employment seemed to be relatively stable in El Cerro where the aquaculture industry supports local food consumption, in Yaxbe, many ejidarios were left with no choice but to find work outside of the ejido in manufacturing, tourism and industry jobs. These jobs offered very low wages, and were sometimes only seasonal. In addition, divergence of the shrimp farm industry in Sonora, where major foreign investment resulted in exporting the majority of all the shrimp harvested, caused an increase in debt levels of the ejiditarios, and more uneven distribution of resource amongst community members due to ocean based environmental problems that caused the shrimp population to collapse.

On the other hand, in Yaxbe, located in Yucatan, close to Cancun and other popular tourist destinations, divergence is beneficial to ejiditarios in the short term in that ejidarios can sell farms for retirement funds. This does help people living in poverty access basic needs such as food, shelter and health care. However, it does not contribute to the overall resiliency of the ejido structure, as land is sold off, many times bought up by foreign owned tourist companies, or taken over by urban growth. The ultimate result is a loss in the form and function of a communal agricultural land.

Overall, the aggregate trend towards divergence after the Mexican land reforms seem to have damaged the form and function of most ejidos in the case studies, even if, like Yaxbe, the benefits are clear in the short term. The economy in El Cerro shows that convergence helps to maintain stable income for the ejidarios. In Sonora, the increase in scale and foreign ownership that accompanied the divergence (and increased export crops) resulted in an overburdened environment and lack of access to a means of food production for those who had lost jobs with big export crop firms.

Conclusion

In some cases where land demand is high, divergence can help farmers in the short term by selling their land, or leasing it to a commercial corporation, this type of activity is seen as a relatively short term solution that often results in an aggregate shift to low wage income earners. Although NAFTA has been well underway for a number of years now and it would be very difficult to re-open (Jacinto, 2008). Just as Thomas saw in Tanzania in the 1970s, while heavy foreign capital investments and the elimination of protective tariffs and trade barriers helps boost national GDP, and exports from a country, they can cause a struggle for people in impoverished rural areas to access their basic needs. While increasing global trade and capital investment in projects can work well in first world, adequately diverse economies, when dealing with extreme poverty, where access to food, shelter and health care can be in jeopardy, a destabilization such as the land and policy reforms in Mexico can be very harmful. These three case studies are a small sample size but, couched in convergence theory, they nonetheless shed light on how and why a community may be more resilient when its economy is more focused on meeting its immediate local needs. Income stability, decreased risk of population loss, less pressure on ejidarios to travel long distances away from their home to work, less incentive to move away from the ejido and a more careful balance of scale of production to avoid environmental issues or the collapse of a food source species were primary ways in which convergence increased resilience in Mexican ejidos.

References

- Vázquez Castillo, M. T. (2004). Land Privatization in Mexico: Urbanization, Formation of Regions and Globalization in Ejidos. New York, US: Routledge.
- Barnes, G. (2009). The evolution and resilience of community-based land tenure in rural Mexico. *Land Use Policy*, *26* (2), 393-400.
- BBC. (2012, Jan 23). Farmers ask for help after severe drought in Northern Mexico. Accessed Feb 1st 2012 from: http://www.bbc.co.uk/news/world-latin-america-16680037
- Bonnis, G., & Legg, W. (1997, June). The opening of Mexican agriculture. Retrieved March 6, 2012, from OECD Observer: http://www.oecdobserver.org/news/fullstory.php/ aid/2728/The_Opening_of_Mexican_Agriculture.html
- Broholm, S. (2012). Revisiting NAFTA: The Gap Between Prediction and Reality for Mexico's Small Corn Farmers. *Journal of Politics and Society*, 21, 1-23. accessed from: http://www.helvidius.org/archive/
- Cruz-Torres, M. L. (2004). On Top of a Hill: The Structure and Organization of a Mexican Ejido. In *Lives of Dust and Water: An Anthropology of Change and Resistance in Northwestern Mexico* (pp. 120-155). Tucson, Arizona, US: The University of Arizona Press.
- Deininger, K., Bresciani, F. (2001). Mexico's *ejido* reforms: Their impact on the functioning of factor markets and land access. World Bank. Selected paper from American Agricultural Economics Annual Meeting. Accessed January 24th 2013 from: http://ageconsearch.umn.edu/bitstream/20519/1/sp01de05.pdf
- Farley, K. A., Ojeda-Revah, L., Atkinson, E. E., & Eaton-Gonzalez, B. R. (2012). Changes in land use, land tenure, and landscape fragmentation in the Tijuana River Watershed following reform of the ejido sector. *Land Use Policy*, 29 (1), 187-197. 10.1016/j.landusepol.2011.06.006
- Getz, C. (2008). Social Capital, Organic Agriculture, and Sustainable Livelihood Security: Rethinking Agrarian Change in Mexico. *Rural Sociology*, 73 (4), 555-579. 10.1526/003601108786471521
- Hull, C. (2007). From Field to Factory and Beyond: New Strategies for New Realities in a Yucatecan Village. In G. Spindler, & J. Stockard, *Globalization and Change in Fifteen Cultures* (pp. 172-198). Belmont, CA: Thomson Wadsworth.
- Haenn, N. (2006). The changing and enduring ejido: a state and regional examination of Mexico's land tenure counter-reforms. *Land Use Policy*, 23 (2), 136-146.
- Jacinto, M. (2008, April 1). Calderón, NAFTA, and Mexico's Campesinos in 2008. Retrieved March 6, 2012, from Council on Hemispheric Affairs: http://www.coha.org/calderon-nafta-and-mexico%E2%80%99s-campesinos-in-2008/
- Luers, A. L., Naylor, R. L., & Matson, P. A. (2006). A case study of land reform and coastal land transformation in southern Sonora, Mexico. *Land Use Policy*, 23 (4), 436-447.
- Nuijten, M. (2004). Peasant 'participation', rural property and the state in western Mexico. *Journal of Peasant Studies*, 31 (2), 181-209.
- Perramond, E. (2008). The rise, fall and reconfiguration of the Mexican ejido. *Geographical Review*, *98* (3), 356-371.

- Thomas, C. Y. (1974). Dependence and Transformation: The Economics of the Transition to *Socialism*. New York, US: Monthly Review Press.
- Deininger, K., Bresciani, F. (2001). Mexico's *ejido* reforms: Their impact on the functioning of factor markets and land access. World Bank. Selected paper from American Agricultural Economics Annual Meeting. Accessed January 24th 2013 from: http://ageconsearch.umn.edu/bitstream/20519/1/sp01de05.pdf
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