ACCELERATE BC

BC's Graduate Research Internship Program

Internship Proposal Submission Template

Instructions

- Proposal should be written and submitted by graduate student or post doctoral fellow **at least 4 weeks prior the planned start date of the internship.**
- Should be no more than 3 pages in length
- A complete proposal must include:
  - The internship proposal using the electronic internship proposal submission template
  - The completed Memorandum (pages 5 & 6 of this document) which is to be faxed to 778.782.6657
  - A current CV of the proposal intern (If required, a CV template is included at the end of this document)
  - The signed Appendix A for the supervising professor (see "Guidelines & Application Procedure" in the BC section at www.mitacsinternships.ca under "Application Requirements."
  - The signed Appendix A for the proposed intern
- Partner funds must be sent directly to MITACS upon approval of the internship proposal

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Research Areas (Specific keywords): Censored data, non-detects, method detection limit, likelihood, robust methods, non-parametric methods, survival methods

Title of Project: Development of statistical methods for data sets containing non-detects
Period of Internship: September 2008 – March 2008
Date of Submission: February 18, 2008

Is this internship related to a MITACS NCE project?
No

Participants

Intern:

Name:	Huston, Carolyn
Degree program:	PhD
University & Department:	Stat. and Act. Science, Simon Fraser University
Address (at university):	8888 University Drive
City, Province:	Burnaby, BC
Postal code:	V5A 1S6
Phone:	778-782-7071
Fax:	778-782-4368
Email:	chuston@sfu.ca

Male/Female:	Female
Citizenship:	Canadian

Academic supervisor:

Name:	Schwarz, Carl J
University & Department:	Stat. and Act. Science, Simon Fraser University
Address:	8888 University Drive
City, Province:	Burnaby, BC
Postal code:	V5A 1S6
Phone:	778-782-3376
Fax:	778-782-4368
Email:	cschwarz@stat.sfu.ca

Organization Sponsor:

Name:	Budhwa, Rick
Position:	Research Program Manager
Department/Division:	Research
Organization:	Bulkley Valley Centre for Natural Resources Research and Management
Address:	BV Research Centre 1188 Main Street (Room 2 Ground Floor) Box 4274
City, Province:	Smithers, BC
Postal code:	V0J 2N0
Phone:	250-847-2827
Fax:	250-847-2848
Email:	rick.budhwa@bvcentre.ca

Proposal

1. Background information

a) *From the partner's perspective*

The Bulkley Valley Centre for Natural Resources Research, a not-for-profit society, strives to advance scientific and technical knowledge in environmentally focused research in concert with a variety of stakeholders and partners including industry and the B.C. government. This research can include environmental monitoring to provide assessment of compliance, and ongoing evaluation of environmental quality. These monitoring activities are intended to accurately report on current ambient environmental conditions and to measure progress in order to facilitate making science based management decisions.

The data collected from these monitoring activities are complex. Studies are conducted under many conditions and often over extended time periods during which collection and analysis technology can change. This can result in data where the amount of information available from different collection periods will vary. In particular, water quality data sets often contain observed values below the method detection limit (MDL). These values are often referred to as 'less-thans' or 'non-detects' because they are reported as being 'below' a certain threshold of detection, but are not known more specifically than that. Because experimental technology can change over time, sampling conditions can change, and this means that a single data set can contain several different MDL's.

Currently the BV Research Centre (and subsequently their partners) lacks a standard protocol for the statistical analysis of water quality data sets containing values below the MDL. The current practice is to use substitution of values below the MDL with arbitrary (fabricated) numbers such as the MDL itself, ½ the MDL, or zero. Unfortunately, substitution is recommended as the treatment for non-detects by many agencies, and is even currently suggested on the website of the Environmental Protection Agency in the United States! Despite the prevalence of its use, numerous statistical studies have shown that such substitutions can lead to biased estimates and incorrect statistical conclusions, and this technique should be abandoned.

Recognizing inadequacies in their current analysis methods, the BV Research Centre is interested in obtaining expert assistance to develop a guidance document to assist them in applying the most modern and relevant statistical methods for analyzing data including non-detects. This document will constitute a significant information technology transfer between statistics and water quality and environmental management protocols in the province of B.C. Creating it will involve investigating current 'best practice' in statistics for dealing with MDL; developing new computer code and documentation to support and explain these techniques; and establishing new methodology as needed.

b) *From the intern's perspective*
Water quality data is often used for performance monitoring and evaluation. These evaluations often compare the mean, variance, or percentiles of the distribution of values across areas (using methods such as two sample, paired t-tests, and Analysis of Variance (ANOVA) methods for comparing mean) or over time (linear, non-linear, or multiple regression for comparing means or percentiles).

All of these methods rely on certain common assumptions including equal variances within groups or along trend lines; error measures being approximately normally distributed; and independent observations. In the presence of non-detects, it is nearly impossible to evaluate the equal variance assumption because variance estimation depends on all the observed values, and in water quality data non-detects are common. It is also rare to see normally distributed water quality data. This is due both to non-detects truncating the observed distribution at the MDL, and also because water quality measures typically evidence strong skewness. Ironically, although both these assumptions are generally violated in water quality data, the analysis techniques listed in paragraph one are often erroneously applied in industry due to a lack of more informed options being easily accessible.

In another area of statistics, survival analysis, it is common to have data sets that are skewed and right censored, meaning that the upper values in the data are not known. This is the complement problem to that existing in water quality data, where the lowest values of the data are not known. There is a large body of literature, and widely available statistical software for analyzing such right censored data using survival methods. Unfortunately, these survival analysis methods are rarely used in water quality analyses because analysts dealing with water quality data cannot keep abreast of advances in survival analysis in addition

to their own field. Many survival analysis methods could therefore be applied in analogous situations in water quality research.

2. Research to be performed. *Include references where applicable.*

The proposed research has several components. First among these is conducting a detailed literature review on methods available for left censored data, and censored data in general. After consultation with the partner organization to review their specific analysis concerns, we will build a body of methodology in the following three ways: 1) Based on already existing methods for left censored data 2) By adapting methods for right censored (survival) data 3) and in developing new statistical approaches as needed for specific sampling situations. After appropriate statistical methods are identified, computer code will be written in R such that the appropriate methods can be easily and directly applied to existing water quality data sets by scientists associated with the BV Research Centre. Finally, to support the use of these new methods, a guidance document will be written outlining the correct methods for left censored data methods; the constraints of these methods; how to implement the R code; and how to correctly interpret the results.

The following lists some of the methods and ideas for analyzing censored data that will be adapted for use in a water quality data framework based on topics that the partner organization has already expressed an interest in. In all cases, a discussion of how to estimate appropriate measures of precision such as standard errors and confidence intervals will be included.

(a) Development of estimators allowing for evaluating evidence of differences in the mean or variance in water quality response variables between two groups, or before and after remedial treatments (repeated measures). Estimates of precision in these experimental circumstances will be developed for when the percent censoring is less than 50% (Gleit,1985; Helsel and Cohn, 1988; Helsel, 2005; Millard and Deverel, 1988).

(b) Extending the ideas from above, methodology and computer code will be developed to analyze censored data when there are 3 or more groups in the data , or discrete covariates(Eckhardt et al., 1989; Lee and Wang, 2003; Lawless,2003; Helsel, 2005)

(c) The ability to detect trends through time is useful, especially when evaluating what impact a particular management decision might have had in the environment. To help discern patterns in the data, we will develop methodology allowing for the detection of trends through time or based on other continuous covariates (Montgomery et al., 2001; Helsel, 2005). This will include the development of both estimates of trends and estimates on the precision of trends in the presence of censored data (Helsel and Hirsch, 2002; Kendall, 1955; Meeker and Escobar, 1998; Tobin, 1958).

(d) Depending on environmental factors, resources, and financing, sample sizes in some years or locations might be smaller than is desirable. To enhance the above methodology, we also discuss how to extend the topics of (a) (b) and (c) when

sample sizes are small and contain non-detects (Theil, 1950; Hirsch and Slack, 1984).

(e) Multiple labs and different individuals are often involved with analyzing water samples. Because of this, the reported value of the MDL can change within a single sample depending on where it is analyzed, and by whom. Additionally, laboratory standards and techniques can change over time so we plan to develop methodology to account for multiple censoring limits (Akritas, 1992, Kendall, 1955).

(f) Finally, some samples have such a high degree of censoring (>50%) that the assumptions of many common techniques cannot be adapted to account for the unknown values. Here we develop alternative analysis methods to gain information from samples where severe censoring is present (Conover, 1999; McCullagh and Nelder, 1989; Helsel, 2005).

3. **Methods or techniques to be applied.** *Please provide enough detail to enable a scientific reviewer to evaluate the proposed methods and techniques.*

It has been repeatedly shown that substituting unknown concentration observations with arbitrary values and using traditional statistical methods leads to poor estimation results (Gleit,1985; Helsel and Cohn, 1985; Singh and Nocerino, 2002). When sample sizes are large, a more appropriate solution is to apply parametric maximum likelihood methods to the data to estimate parameters of interest. When sample sizes are smaller, or do not meet distributional assumptions, alternative estimates based semi-parametric methods to estimation need to be developed and applied (Helsel, 2005).

Standard regression techniques can be used to across groups or other categorical covariates, and to look for linear trends in data. Regression for censored data (Helsel, 2005) allows for similar analyses when censored, or non-detect data are present. These specialized methods will be showcased for use when sample sizes are large, and data can be assumed to follow normal or lognormal distributions.

In the small sample situations, or when normal or lognormal assumptions are not practical, non-parametric analogues will be used. There are many methods for censored data used in survival analysis studies which are typically right censored (Lee and Wang, 2003; Lawless, 2003). Water quality data are typically left censored, so an important task will be adapting survival (right censored) methods to left censored data. Some tests to be considered are variations on the rank sum test, Mann-Whitney test (when multiple detection limits are present), the Gehan test (Gehan, 1965), and a variety of other score tests (Helsel, 2005; Conover and Iman, 1981).

Extending non-parametric tests to situations with three or more groups, or continuous covariates is more complicated than when estimating in the maximum likelihood framework. Two possible methods for comparing group centres include the Kruskal-Wallis test, and the Wilcoxon score test. As before, these are most commonly implemented on right-censored survival data, and so computing methods will have to be adapted so they are suitable for left censored data.

Suitable methods for multiple comparisons to estimate the differences among the mean/median of groups will also be adapted.

In the non-parametric context, linear trends can be assessed using Spearman's rho, which is a measure of monotonic association between Y and X variables (Helsel and Hirsch, 2002). When multiple detection limits occur, Kendall's tau (Kendall, 1955) can provide an alternative measure of association between continuous variables of interest. Estimates of actual regression trends using non-parametric methods can be assessed using the Theil-Sen slope or one of its adaptations (Theil, 1950; Sen, 1968; Hirsch and Slack, 1984). Reasonable bounds of precisions can be placed on these slopes can be computed based on iterative estimation (Turnbull, 1976). All of these methods should prove useful in developing standard water quality data analysis methodology.

One last topic of importance is in addressing data analysis when the percentage of non-detect values is >50%. The most promising approach appears to be approximating the data to a binomial format divided into observations falling above and below the detection limits. Analysis techniques for contingency tables can then be used to compare groups and discrete covariates, and methods such as logistic regression can be used to calculate the probability of exceeding the detection limit when continuous covariates are considered (Helsel, 2005; McCullagh and Nelder, 1989).

References:

Akritas, M.G., 1992, Rank transform statistics with censored data: *Statistics and Probability Letters* 13, 209-221.

Conover, W.J., 1999, *Practical Nonparametric Statistics,* Third Edition. Wiley, New York, 584 pp.

Conover, W.J. and R.L.Iman, 1981, Rank transformations as a bridge between parametric and nonparametric statistics: *American Statistician* 35, 124-129.

Eckhardt, D.A., W.J.Flipse and E.T.Oaksford, 1989, Relation between land use and ground water quality in the upper glacial aquifer in Nassau and Suffolk Counties, Long Island NY: U.S. Geological Survey Water Resources Investigations Report 86-4142, 26 pp.

Gehan, E.A., 1965, A generalized Wilcoxon test for comparing arbitrarily censored singly censored samples: *Biometrika* 52, 203-223.

Gleit, A., 1985, Estimation for small normal data sets with detection limits. *Environmental Science and Technology* 19, 1201-1206.

Helsel, D.R,, 2005, *Nondetects and data analysis: Statistics for censored environmental data.* First Edition. Wiley Interscience, Hoboken, NJ.

Helsel, D.R., and T.A. Cohn, 1988, Estimation of descriptive statistics for multiply censored water quality data: *Water Resources Research* 24, 1997-2004.

Helsel, D.R. and R.M. Hirsch, 2002, Statistical Methods in Water Resources. U.S. Geological Survey Techniques of Water Resources Investigations, Book 4, Chapter A3, 512 pp.

Hirsch, R.M. and J.R. Slack, 1984, A nonparametric trend test for seasonal data with serial dependence: *Water Resources Research* 23, 727-732.

Kendall, M.G. 1955. *Rank Correlation Methods,* Second Edition. Charles Griffin and Company, London, 196 p.

Lawless, J.F., 2003, *Statistical Models and Methods for Lifetime Data*, Second Edition. Wiley Interscience, Hoboken, NJ.

Lee, E.T., and J.W. Wang, 2003, *Statistical Methods for Survival Data Analysis,* Third Edition. Wiley, New York, 534 pp.

McCullagh, P., and J.A. Nelder, 1989, *Generalized Linear Models*, Third Edition. Chapman and Hall, New York.

Meeker, W.O, and L.A. Escobar, 1998, *Statistical Methods for Reliability Data.* Wiley, New York, 680 pp.

Millard, S.P. and S.J. Deverel, 1988, Nonparametric statistical methods for comparing two sites based on data with multiple nondetect limits: *Water Resources Research* 24, 2087-2098.

Montgomery, D.C., Peck, E.A., and G.G. Vining, 2001, *Introduction to Linear Regression Analysis,* Third Edition. Wiley, New York.

Sen, P.K., 1968, Estimates of the regression coefficient based on Kendall's tau: *Journal of the American Statistical Association* 63, 1379-1389.

Singh, A., and J. Nocerino, 2002, Robust estimation of mean and variance using environmental data sets with below detection limit observations; Chemometrics and Intelligent Laboratory Systems 60, 69-86.

Theil, H., 1950, A rank invariant method of linear and polynomial regression analysis: *Nederl. Akad. Wetensch, Proceed.,* 53, 386-392.

Tobin, J. 1958, Estimation of relationships for limited dependent variables: *Econometrica* 26, 24-26.

Turnbull, B.W., 1976, A likelihood ratio test statistic for goodness of fit with randomly censored data. *Biometrics,* 34, 367-375.

4. **Relevance to partner organization**, *stating how the partner will benefit from participating in the internship.*

The government of British Columbia has a goal to "Lead the world in sustainable environmental management, with the best air and water quality and best fisheries

management, bar none." Monitoring and reporting on ambient environmental quality to measure progress and inform management decisions is therefore an important part of achieving this mandate. Improving the way data are analyzed through the proposed methodology developments listed above will be an important component toward strengthening science based decision making in British Columbia based on the broad network of organizations that partner with the BV Research Centre. The final report from the project will be a valuable document for distribution to partner organizations in order to improve the standards of data analysis techniques. This will allow for better impact prediction, and the selection of the best mitigation measures to avoid negative environmental impacts.

5. **Expected interaction with partner.** *Please indicate the number or weeks (or % of time) during the internship that the intern will spend on site with the partner as well as the nature of the interaction. If the partner location where the intern will be spending time is different from the partner's address specified on page one, please note the address of the second partner site.*

For the first month, the intern will spend most of her time on site to understand the data, review sampling plans, and meet with scientists working for and contracting with the BV Research Centre regarding specific concerns they want addressed over the course of the internship. Following the first month, Carolyn will spend time working at SFU in order to develop methodology, write code, and complete a reference document as a deliverable to the BV Research Centre. This document will include information on the best techniques to use when analyzing data including non-detects; examples of such data sets containing non-detects from the Research Centre; and detailed instructions and code on how to analyze such data sets using R, and where possible, JMP statistical software.

Following completion of this document, Carolyn will spend another block of time with the BV Research Centre revising the document based on input from scientists, and also educating partners associated with the BV Research Centre on how to use the new statistical software, and how to interpret the statistical results. Altogether Carolyn will spend approximately 50% of her time on site working with the BV Research Centre in Smithers, or at an associated site.

6. **Research milestones and timeline***, indicating on a month-by-month (or week-by-week, if required) basis how the research project is planned and when key milestones will be addressed.*

September 2008 to March 2009.

We expect that it will take approximately one month of time to complete initial meetings with the BV Research Centre, and to assess the types of data being collected and their specific analysis needs. Following this, we anticipate that it will take approximately 2 months to develop methodology, create computer algorithms, and write an initial draft of a guidance document for the analysis of non-detects. Following this, we have allocated approximately a month of time to be spent with the BV Research Centre revising the document and training scientists in using the methodologies proposed.

Although 4 months work will be completed, depending on the availability of interested parties at the BV Research Centre completing the project could take the intern up to 7 months allowing for some gaps in the work schedule.

7. Relationship to past/other internships where relevant

None.

8. **Proposed budget** *including details of projected expenses, including intern's stipend. Please note that for a 4-month internship, approximately 10,000 must be provided to the intern as a stipend. Please also indicate how the remaining funds will be allocated in support of the research.*

Partner Contribution:	$ 7,500
MITACS Contribution:	$ 7,500
TOTAL:	$15,000

Expenses:

Student Stipend	$10,000
Consumables	$ 500
IRMACS space	$ 500
Travel Expenses	$ 3,000
Computing supplies	$ 1,000
TOTAL	$15,000

8b. Will the intern be applying for an additional travel subsidy over and above what may be in the proposed budget? *If so, please outline projected expenses.*

Additional funds are requested. Because this project involves extensive travel between SFU, Smithers B.C. and BV Research Centre partner locations an additional $2000 is requested to cover travel and accommodation expenses. Combined with the regular expenses, this allows for travel expenses of $5000 a breakdown of which is shown below. This is intended to provide for 2 months (60 days) of time spent in Smithers.

Travel Expenses:

Flights	$1,640	(2-3 flights between Smithers and Vancouver at ~$547 per flight based on Air Canada and Hawkair online prices)
Accommodation	$2,460	($41 per night for ~60 nights at the Smithers Hostel and Guesthouse)
Food	$ 900	(~$15 per day based on a 60 day stay assuming use of a kitchen at the hostel)
Total	$5,000	

9. **Is the academic supervisor an owner or a co-owner of the partner organization, or does the supervisor participate in the day-to-day management of the organization?** *If so, please complete the Conflict of Interest Declaration.*

No.

10. **Does the proposed research involve living human subjects or human remains?** *If so the proposal must be reviewed by the participating University Research Ethics Board prior to submission to MITACS, and a report by such board must be included with the application.*

No.

10b. **Does the proposed research involve animal subjects?** *If so the proposal must be reviewed by the participating University Animal Care Committee prior to submission to MITACS, and a report from such a committee must be included with the application.*

No.

11. Will the proposed research be taking place outside of the lab? *If so, please indicate what if any, impact there may be on the environment.*

No.

12. **Are the industry funds of this internship being or going to be leveraged elsewhere?** *If so, please declare with what organization and the amount.*

No

ACCELERATE BC – Memorandum

BC's Graduate Research Internship Program

The participants listed below have agreed to set in place an Internship based upon the attached proposal. It is understood that the organization sponsor contribution shall be provided to MITACS Inc. prior to commencement of the Internship, at which time MITACS shall award a research grant to the supervising professor. It is further understood that the intern's appointment at the university shall be treated as scholarship and the intern, as well as the supervisor, shall be covered under the university WCB and other applicable insurance policies once placed on university payroll. All parties also agree that the intern shall retain the right to publish the results of the project and is expected to provide MITACS with a completion report and complete an exit survey within 1 month of project completion.

All parties involved with ACCELERATE BC are bound by the intellectual property and internship terms of the university where the intern is enrolled. Please follow this link and click on "Intellectual Property" to find the terms of the various universities. By signing this memorandum, you are acknowledging that you have read, and agree to, the terms of the university where the intern is enrolled.

The participants listed below also agree that MITACS can disclose personal information included in this proposal to the program's funding partners for the purpose of evaluating the Internship Program and its outcomes.

Title of Project:

Period of Internship:

Overview of Project: Please provide a general, one-paragraph description of the research project that the intern will be undertaking at the organization, *using simplified language understandable to a layperson*. (**Approx 150 words**)

The student's research at the Bulkley Valley Research Centre is to create a guidance document intended to improve current practice in analyzing water quality data containing observations below the method detection limit (MDL). Monitoring water quality is an important part of evaluating the environment. Unfortunately, the present standard protocols in British Columbia are known to create biased statistical results and unreliable conclusions.

By thoroughly reviewing current data collection methods, and researching the most topical statistical literature, the guidance document created will represent a valuable contribution to addressing current problems in water quality research in British Columbia. Containing up to date statistical methods, new methods as needed, and the computer code required to support straightforward analysis using the featured methods, this document will significantly advance industry's ability to make sustainable management decisions based correct and useful scientific information.

Participants

Intern: Name Carolyn Huston

Department Statistics and Actuarial Science

University Simon Fraser University

Signature_____ Date_____

Supervisor: Name

Department

University

Signature_____ Date_____

Organization Sponsor: Name

Position

Organization

Signature_____ Date_____

Office of Research Services Representative: Name

Position

Signature_____ Date_____

MITACS Inc. Representative: Name

Position

Signature_____ Date_____

***Please note that the information above including the title of the project, description of research project, name of partner company, name of intern, name of supervisor and involved university may be used by MITACS to publicize the ACCELERATE BC program.*

CHECKLIST: Please note that a complete internship application package includes the following.

☐ Internship proposal (electronic version required)

☐ Memorandum (signed by all parties)

☐ Student CV

☐ Appendix As (signed by supervising professor and student)

****Please note that an incomplete application will result in a delay of the internship evaluation process.**

SUBMISSION INSTRUCTIONS

Please fax a copy of the signed Memorandum and Appendix As to 778.782.6657 and email the proposal and student CV to the ACCELERATE BC representative with whom you have been dealing:

- Karen Booth at kbooth@mitacs.ca
- David Makihara at dmakihara@mitacs.ca
- Laurence Meadows at lmeadows@mitacs.ca
- Duncan Phillips at dphillips@mitacs.ca

ACCELERATE BC gratefully acknowledges the financial support of the Province of British Columbia through the Ministry of Advanced Education. We would also like to acknowledge the support of Western Economic Diversification, Simon Fraser University, the University of British Columbia, the University of Northern British Columbia and the University of Victoria.

ACCELERATE BC

BC's Graduate Research Internship Program

Student CV Template

Date February 26, 2008	
Family Name **Huston**	Given Name **Carolyn**

ACADEMIC BACKGROUND

Degree	Name of Discipline	Institution	Country	Date
B.Sc. w/ Distinction	Conservation Biology major, Philosophy minor	University of Alberta	Canada	September 1998-June 2002
M.Sc.	Biostatistics	University of Alberta	Canada	September 2003-June 2005
Ph.D.	Statistics	Simon Fraser University	Canada	September 2005-July 2009

ACADEMIC, RESEARCH & INDUSTRIAL EXPERIENCE

Position held	Organization	Department	Period (yyyy/mm to yyyy/mm)
Research Assistant	University of Alberta	Renewable Resources	2001/04-2002/05
Teaching Assistant	University of Alberta	Mathematics and Statistics	2003/01-2005/04
Research Assistant	University of Alberta	Mathematics and Statistics/Pediatrics	2003/01-2005/04
Course Instructor	University of Alberta	Mathematics and Statistics	2005/01-2005/04
Teaching Assistant	University of Alberta	Medicine and Dentistry	2005/01-2005/06
Research Assistant	Department of Fisheries and Oceans/SFU	Pelagic Research/ Statistics and Actuarial Science	2005/10-2006/02
Research Assistant	SFU/Vancouver Aquarium	Statistics and Actuarial Science/Marine Research	2005/09-present
Teaching Assistant/Course Instructor	SFU	Statistics and Actuarial Science	2006/09-2007/04

DESCRIPTION OF ACTIVITIES AT ACADEMIC INSTITUTIONS

Provide details of published papers, title of dissertation and name of supervisor and other

relevant activities.

Articles published or accepted in refereed journals:

Stadt, K. J., **Huston, C.,** Coates, K. D., Feng, Z., Mark R.T., Lieffers, V. J. (2007) Evaluation of competition and light estimation indices for predicting diameter growth in mature boreal mixed forests. Annals of Forest Science. V.64 n.5: 477-490

Rosychuk, R.J., **Huston, C.,** Prasad, N.G,N. (2006) Spatial event cluster detection using a compound poisson distribution. Biometrics. 62: 465-470

Flores-Mire, C., Palmer, N.G., Northcott, H.C., **Huston, C.,** Major, P.W. (2006) Computer and internet usage by Canadian dentists. Journal of the Canadian Dental Association. Vol 72(2):145-147

Chiarella, A.B., Jolly, D.T., **Huston, C.M.,** Clanachan, A.S. (2003). Comparison of four strategies to reduce the pain associated with intravenous administration of Rocuronium. British Journal of Anaesthesia. 90:1-3

Thesis Dissertations:

Master's Thesis:
Title: Parasuicide cluster detection in Alberta Regional Health Authorities taking repeat Emergency Room visits into consideration.
Supervisors: Dr. Prasad, Dr. Rosychuk, University of Alberta

Undergraduate Thesis:
Title: A comparison of non-spatial and spatial empirical and resource-based competition indices for predicting the diameter growth of trees in maturing boreal mixed-wood stands.
Supervisors: Dr. Lieffers, Dr.Dale, University of Alberta

Other Relevant Activities:

Huston, C., Schwarz, C.J., Schweigert, J., Flostrand, L. (2007) Finding the fish: looking at movement trends in Pacific herring populations. Statistical Society of Canada 2007 Meeting, June 10-13. Session 04F, Statistics and the environment (also presented at the CMS-MITACS Joint Conference 2007)

Huston, C., Marliave, J., Welch, D. (2007) Acoustic tagging of transplanted black rockfish. Georgia Basin Puget Sound Research Conference, March 26-29. Poster Group 2: Invasive and Recovering Species

Chiarella, A.B., Jolly, D.T., **Huston, C.M.,** Clanachan, A.S. (2002) 8.4% Sodium bicarbonate significantly reduces the pain associated with the intravenous injection of a pre-curarization dose of Rocuronium. Anaesthesia and Analgesia. 94; S-210. International Anaesthesia Research Society (IARS) 76th Clinical and Scientific Congress, San Diego, California, March 16-20

Stadt, K.J., **Huston, C.,** Lieffers, V.J. (2002) A comparison of non-spatial and spatial empirical and resource-based competition indices for predicting the diameter growth of trees in maturing boreal mixedwoods stands. Sustainable Forest Management (SFM) Network Final Report

AREAS OF EXPERTISE Provide a maximum of 10 words that describe your area(s) of expertise.
Creating/adapting statistical methods appropriate for environmental and other sciences.