Proceedings of the NORTH DAKOTA Academy of Science

88th Annual Meeting

April 1996 Volume 50

(-:} {:-(

PROCEEDINGS of the NORTH DAKOTA ACADEMY of SCIENCE is published annually. This issue contains communications (from Symposia, from Professional Contribution sessions, and from Collegiate Competition sessions) representing papers submitted and accepted for oral presentation at the April annual meeting of the ACADEMY. The PROCEEDINGS appears in April of each year.

Annual dues for **ACADEMY membership** are:

$15.00 for regular professional members,
$ 5.00 for student members, and
Corporate Sustaining memberships:
  $100.00 for patron members and
  $ 50.00 for sponsor members.

Subscriptions:

All members of the ACADEMY receive the PROCEEDINGS either at the Annual Meeting or subsequently by mail at no additional charge.

Copies of the PROCEEDINGS may be purchased separately for

$10.00 per copy, prepaid at the meeting or for
$10.00 plus a postage and handling fee of $3.00 by mail.

Correspondence concerning subscriptions (standing orders), as well as instructions for authors and other related matters, should be directed to:

Office of the Secretary-Treasurer
North Dakota Academy of Science
Post Office Box 5567
University Station
Fargo, North Dakota 58105

The PROCEEDINGS is printed by Richtman's Printing, Fargo

ISBN 0096 - 9214

:-((-:

[:-))-:]

P R O C E E D I N G S

Volume 5 0 April 1 9 9 6

= =

NORTH DAKOTA ACADEMY of SCIENCE

(Official State Academy 1958 Founded December 1908)

1 9 9 5 - 9 6

OFFICERS and MEMBERS of the EXECUTIVE COMMITTEE

88th ANNUAL MEETING

25 - 26 April, 1996

Valley City, North Dakota

{-;> >;-{

EDITOR's NOTES

The PROCEEDINGS of the NORTH DAKOTA ACADEMY of SCIENCE was first published in 1948 with Volume I reporting the business and scientific papers presented for the Fortieth Annual Meeting, 2 and 3 May, 1947. Through Volume XXI the single yearly issue of the PROCEEDINGS included both Abstracts and Full Papers. Commencing with Volume XXII, the PROCEEDINGS was published in two parts. Part A, published before the meeting, contained an Abstract of each paper to be presented at the meeting. Part B, published later, contained full papers by some of the presenters.

Commencing in 1979 with Volume 33, the PROCEEDINGS changed to the present format. It is produced from camera-ready copy submitted by authors, and is issued in a single part to be distributed initially at the Annual Meeting in late April. Each *Collegiate* and *Professional* presentation at the Annual Meeting is represented by a full page "Communication" which is more than an abstract, but less than a full paper. The communications contain actual results and conclusions, and permit data presentation. The communication conveys much more to the reader than did an abstract, but still provides the advantage of timeliness and ease of production. Commencing with Volume 50, presenters of the Symposia of the 88th Annual Meeting are given the opportunity of contributing an expanded ***Review of the State of the Science*** consisting of a multiple page contribution providing a presentation of much greater depth and scope than possible in a "single page communication". It is hoped that such contributions might become acceptable to administrators for use in support of promotion/tenure applications.

The Communications of this volume of the PROCEEDINGS are presented in three sections. One section contains presentations from the Symposium offered at the 88th Annual Meeting of the Academy. These papers are organized in the same sequence as presented at the meeting.

A second section of this volume contains the communications presented in the Professional sections of the meeting. All Professional Communications were reviewed for conformity with the instructions to authors by the Editorial Committee prior to their acceptance for presentation and publication herein. The professional communications have been grouped together in order of the oral presentation at the Annual Meeting.

A third section of this volume presents the Collegiate Communications representing all those papers presented in the **A. RODGER DENISON Student Research Paper Competition.** Undergraduate and graduate students reported on the results of their own research activities, usually carried on under the guidance of a faculty advisor. While student competitors were required to prepare a communication similar to those prepared by their professional counterparts, these communications were not reviewed prior to publication herein. The Denison Awards Committee judges the oral presentation and the written communication in arriving at their decision for first place and runner-up awards in both the graduate and undergraduate student competitions. In this section the first group of papers are from the undergraduate competition and the second group of papers are from the graduate competition.

Readers may locate communications by looking within the major sections of these PROCEEDINGS (see the table of contents), or by referring to the author index for a page number reference to this volume.

This issue of the PROCEEDINGS also includes the *Constitution and Bylaws* of the ACADEMY, a list of *Officers and Committee Membership* for the May - April year, a list of all *Academy members* as of March, and a copy of the most recent *financial statement* summarizing the evolutionary status of the Academy.

Roy Garvey

TABLE of CONTENTS

Submission. 1. Papers presented at the Annual Meeting of the ACADEMY must be represented by **single** page communications in the PROCEEDINGS. At least one author must be a member in good standing of the Academy. This includes A Rodger Denison student research competition papers. Exceptions are made in the case of participation in Symposia.

2. Only communications intended for presentation at the Annual Meeting will be considered for publication. They must present **original research** in a concise form. Quantitative data should be presented with statistical analysis (means with standard errors). The communication should include the purpose of the research, the methodology, results, and conclusions. Papers which merely summarize conclusions or ideas without supporting data are discouraged and will not normally be accepted.

3. Communications must be submitted on a single 8.5 x 11.0 inch page of white bond paper. The full surface area of the page may be used for text and figures. Send the **original** and **four legible** photo **copies** to the Editor, PROCEEDINGS of the North Dakota Academy of Science. The original must not be folded; a cardboard stiffener should be used to avoid damage. The Editor will add the headline and footer. The PROCEEDINGS will be published by direct photo offset of the submitted communication with a reduction to 80% of the original size to accommodate margins). No proofs will be prepared. **Authors are encouraged to submit electronic documents** (on 3.5" computer diskettes) suitable for reading on a DOS/WINDOWS/OS2 PC along with the hard copy. Label the outside of the diskette with title of manuscript, authors. Identify the word processing program and version used {WORDPERFECT is preferred, but attempts to convert other formats will be made}. ACADSCI, Inc {abstracts of the state academies of science} request that authors also submit an abstract for inclusion on their DC-ROM database. "Please use only the symbols that are on the computer keyboard" [ASCII only]. These "*abstracts*" will be collected and forwarded on a single diskette.

4. The authors' permission for the North Dakota Academy of Science to publish is implied by a submission. The ACADEMY does not restrict the right of authors to include data presented in a communication in full papers submitted at a later date to other publishers.

5. *Manuscript*. Authors are encouraged to utilize the full space available on an 8.5 x 11.0 inch page in order to provide sufficient information to fully describe the research reported. One or two line top and bottom margins and 1 to 3 character right and left hand margins are recommended (as appropriate to your printer). The material you submit on this page must be "camera-ready" since it will be photographed and reproduced directly in the PROCEEDINGS. Text should be presented using no smaller "elite" (12 character per inch) fonts and single line spacing (6 lines per inch). This should allow for approximately 62 lines of 100 characters each. Unless your printer/word processor uses "micro justification", DO NOT right justify your text. Begin paragraphs with a 3 character space indentation. Use a typewriter with carbon or good quality black silk ribbon, or a "laser printer" set for the narrowest margins which will retain the printed characters on the face of an 8.5 by 11.0 inch page. Special symbols not available on the fixed character printer must be hand lettered in black ink. Dot matrix print of less than "letter quality" is not acceptable.

6. Text, tables and diagrams reproduced on white bond paper, and high contrast photographs may be secured to your original page of text using "Tack Note" by Dennison or with two sided mounting tape. Tape should NOT show on the top side of the bond paper or photograph being mounted. All typing, drawing and secured art or photographic materials must be within the boundaries of the single 8.5 x 11.0 inch page. Brief descriptive captions or titles must accompany each figure and table.

7. *Heading*: The title of the communication, typed in capitalized characters, should be centered as the first line(s). It is suggested that authors select a sufficient number of "keywords" to describe the full content of their paper, and then construct a title using as many of these as practical. Titles normally should not exceed 140 characters in length. They should be free from unnecessary phrases such as "a preliminary investigation of" or "some notes on" which add little or nothing to their meaning. A blank line should follow immediately after the title. The names of the authors should be centered on the line immediately following the blank line after the title of the communication. Full first names are encouraged; however, the author should use initials if that form is normally used in other publications. Indicate the author to present the communication by an asterisk * after that person's name. The business or institutional address of the author(s) should be centered on the line immediately following the line listing the name of the author. Typical entries might be:

Department of Chemistry, North Dakota State University, Fargo, ND 58105
Energy and Environmental Research Center, University of North Dakota, Grand Forks, ND 58202
USDA/ARS, Human Nutrition Research Center, Grand Forks, ND 58202
USDA/ARS, Biosciences Research Laboratory, Fargo, ND 58105
North Dakota Geological Survey, 600 East Boulevard, Bismarck, ND 58505

8. *References*: Only essential references should be cited, and each should be indicated in the text by a number enclosed in parentheses; this number should be on the same line as the rest of the text (e.g. "This topic has been discussed by Smith (5, 6)"). Note that a space is left between words and the parenthetical citation and that there is a space between numbers in multiple citations. References are to be assembled, arranged numerically in order of first appearance in the text, and placed at the end of the communication under a two inch line of _______. In the Literature Cited the reference numbers are followed by a period and are placed flush with the left margin; if the reference exceeds one line, the succeeding line or lines should be indented 5 spaces. The following form of citation should be used. Note that periods after abbreviations for Journal titles and spaces between initials for authors names have been omitted to conserve space.

---

1. Neary, D., Thurston, H. and Pohl, J.E.F. (1973) Proc ND Acad Sci 40, 83.
2. Batsone, G.W., Blair, A.W. and Slater, J.M. (1971) A Handbook of Pre-Natal Pediatrics, pp 83-90. Medical and Technical Publishing, Lancaster.
3. Farah, A.E. and Moe, G.K. (1970) in Pharmacological Basis of Therapeutics, 4th edition (Goodman, L.S and Gilman, A, eds), pp 677-709. MacMillan, New York.
4. Rajewsky, M.F. (1973) Abstr 2nd Meeting European Association of Cancer Research, Heilelberg, Oct 2–5, pp 164–5.

9. *Abbreviations*: Only standard abbreviations should be used, and should be written out the first time used with the abbreviation following in parentheses. The North Dakota Academy of Science (NDAS) for example.

10. *Session Assignment*: To assist the Program Committee in organizing the presentations, please indicate in a cover letter your 1st, 2nd and 3rd preferences for the topical classification of your paper.

RULES for ORAL PRESENTATION of COMMUNICATIONS

1. All papers are limited to 18 minutes total elapsed time for presentation and discussion. It is suggested that the presentation be limited to twelve minutes with an allowance of five minutes for discussion. It is also suggested that major emphasis be placed on the significance of the results and the general principles involved rather on the details of methods and procedures.

2. ACADEMY members represent a variety of scientific disciplines; therefore, speakers should avoid *"jargon"* and briefly explain or define specialized terminology as may be judged to be indispensable to the presentation.

3. Projectors for 2 X 2 inch slides and "overhead transparencies" will be available in all session rooms. Opaque projectors and video playback of computer controlled displays will be made available as required if advanced notice of need is given. Only visuals which can be read easily on projection should be used. Authors who desire suggestions fro preparation of slides are referred to Smith, H.W. (1957) "Presenting Information with 2 x 2 Slides", Agron J, 49, 109-13.

4. Timed rehearsals with slides are highly recommended. There is usually time for a maximum of 6 or 7 slides for a presentation of this kind.

5. Presidors are bound to remain on a strict time schedule in order that members of the audience can easily move among sessions to attend papers of special interest.

Thursday, 25 April

3:30 *CYP1A1* GENE POLYMORPHISMS in HUMAN COLORECTAL CANCER and NON-CANCER SUBJECTS

Timothy R Wilkie*, Mark A Doll, Kevin Gray, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

3:50 FEASIBILITY RESEARCH of an INDOOR AQUACULTURE FACILITY in NORTH DAKOTA

Gregory J Nelson*, Kevin E Ward, Mark K Lamontange, Douglas K Ludlow
Chemical Engineering, University of North Dakota, Grand Forks

4:10 ISOLATION and IDENTIFICATION of 1,4,7,8-TETRACHLORODIBENZO-p-DIOXIN METABOLITES in RAT FECES

Heather Plum*, Janice K Huwe, Vernon J Feil
USDA/ARS Biosciences Research Laboratory, Fargo

4:30 *NAT2* GENE POLYMORPHISMS in HUMAN COLORECTAL CANCER and NON-CANCER SUBJECTS

Shelly L Satran*, Mark A Doll, Kevin Gray, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

4:50 IMPROVED HOLOGRAPHY TECHNIQUES: OPTIMIZING EXPOSURE TIME to REDUCE VIBRATION EFFECTS

Randy R Black Cloud* and Francis L Howell
Physics, University of North Dakota, Grand Forks

CYP1A1 GENE POLYMORPHISMS IN HUMAN COLORECTAL CANCER AND NON-CANCER SUBJECTS

Timothy R. Wilkie*, Mark A. Doll, Kevin Gray, and David W. Hein
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Cytochrome P4501A1 (CYP1A1) is one of a family of cytochrome P450 monooxygenases that activates polycyclic aromatic hydrocarbons such as benzo[a]pyrene to electrophilic metabolites that bind to DNA and initiate tumors. CYP1A1 is inducible, and a genetically determined high inducibility phenotype cosegregates with a polymorphism of the *Msp*I restriction site in the 3′-end of the *CYP1A1* gene. Another CYP1A1 gene polymorphism involves a point mutation resulting in an amino acid substitution (Ile → Val) at amino acid 462 in the heme binding region of CYP1A1. Both *CYP1A1* polymorphisms have been associated with increased risk of colon cancer. We obtained thirty-five human colon samples from the Human Cooperative Tissue Network of the National Cancer Institute. Colon samples were derived from colorectal cancer and non-cancer subjects. DNA was isolated from the colons and *CYP1A1* was amplified by the polymerase chain reaction. The two *CYP1A1* polymorphisms were identified by restriction fragment length polymorphism analysis to test for an association between these *CYP1A1* polymorphisms and colorectal cancer incidence. As shown in Tables 1 and 2 below, an association was not observed in this preliminary study. Partially supported by USPHS grant CA-34627.

Table 1. *CYP1A1* Polymorphism at 3′-End in Colorectal Cancer and Non-Cancer Subjects

	Cancer	Non-Cancer
Total Sample	16	16
Blacks (%)	5 (31%)	4 (27%)
Whites (%)	11 (69%)	11 (73%)
Males (%)	11 (69%)	10 (62%)
Females (%)	5 (31%)	6 (38%)
Age Range	52−76	26−85
Age Mean ± S.D.	63.8 ± 7.9	59.6 ± 17.7
T/T Genotype	11 (69%)	11 (69%)
T/C Genotype	5 (31%)	5 (31%)

Table 2. *CYP1A1* Polymorphism (Ile → Val) in Colorectal Cancer and Non-Cancer Subjects

	Cancer	Non-Cancer
Total Sample	16	14
Blacks (%)	4 (25%)	3 (21.4%)
Whites (%)	12 (75%)	11 (78.6%)
Males (%)	11 (69%)	10 (71.4%)
Females (%)	5 (31%)	4 (28.6%)
Age Range	52−76	31−85
Age Mean ± S.D.	64.9 ± 7.1	61.8 ± 15.8
A/A Genotype	14 (87.5%)	11 (78.6%)
A/G Genotype	2 (12.5%)	3 (21.4%)

Feasibility Research of an Indoor Aquaculture Facility in North Dakota

University of North Dakota, Grand Forks
Gregory J. Nelson*, Kevin E. Ward, Mark K. Lamontagne,
and Dr. Douglas K. Ludlow

The feasibility of building and operating an indoor recirculating aquaculture facility was investigated. More specifically, this paper focuses on the feasibility of operating the facility using North Dakota lignite for heating.

Sources state that the demand for fish increased nearly 25% during the 1980's and is expected to increase at this rate during the 1990's. While the demand for fish has been increasing, the world's natural supply of fish has been decreasing.

Mr. Gene Watne is interested in developing an intensive indoor aquaculture facility to produce tilapia on his farm north of Velva, North Dakota. The system will consist of approximately twenty grow-out tanks containing a total volume of 350,000 gallons. With approximately 263,000 lbs. of fish in the facility at any given time, the annual production is expected to be 1.3 million lbs. of fish. The tilapia will consume a soy-based protein feed. Tilapia fingerlings will be purchased from a supplier.

The grow-out tanks are composed of polypropylene lined circular grain bin rings of various sizes. All of the fresh water to be used in the system will be taken from an aquifer. In order to recirculate the water used in the aquaculture facility a variety of devices have to be used to purify the water. The first of these is an inclined tube settler that is used to settle out the larger waste particles. The next piece of equipment is a rotary screen filter which filters off the intermediate sized particles. After the rotary screen filter, the water passes through a foam fractionator that skims off the smaller sized particles. A biofilter converts the potentially dangerous ammonia into nitrites and then subsequently into nitrates. The high nitrate waste streams are all sent to a lagoon for treatment. An oxygen generation system will supply the oxygen requirements for the system. Using a pumping system, 90 percent of the water will be recirculated.

The current price of tilapia is $1.40-$1.50 per pound with production costs only being $0.85-1.00 per pound with a net profit of $0.40-$0.50 per pound of tilapia. This yields an approximate annual income of $525,000 to $650,000.

Building and operating an aquaculture facility is a complex process. With proper design and construction, along with good management, fish farming has the potential to be a profitable business in North Dakota.

ISOLATION AND IDENTIFICATION OF 1,4,7,8-TETRACHLORODIBENZO-*p*-DIOXIN METABOLITES IN RAT FECES

Heather Plum,* Janice K. Huwe and Vernon J. Feil
USDA/ARS, Biosciences Research Laboratory, Fargo, ND 58105

Dioxins, especially 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), are highly toxic in many species of animals. These are formed by many human activities including all burning processes (1). Dioxin levels in foods have become a concern because airborne dioxins can be deposited on forages which are consumed by food producing animals. Some animals from given areas of the U.S. have been shown to have substantially higher levels of some dioxin congeners than average for that area (2). As part of a large research effort into dioxins and food safety, we initiated a study on the mammalian metabolism of various non-toxic dioxin congeners, i.e., 1,2,7,8-TCDD, 1,3,7,8-TCDD and 1,4,7,8-TCDD. Some aspects of the metabolism of 1,4,7,8-TCDD in the rat will be addressed here.

A dose solution of [^{14}C]-1,4,7,8-TCDD in peanut oil was given orally to six male Sprague-Dawley rats (7 mg/kg). Urine and feces were collected for 72 hrs (at 24 hr intervals), after which time the rats were sacrificed. The 0-24 hr feces were found to contain approximately 42% of the dose by ^{14}C-combustion. This feces sample was freeze-dried and sequentially extracted with hexane, ethyl acetate and methanol. The hexane extract (15.1% of total dose) was then fractionated by Sephadex LH-20 and C18 high performance liquid chromatography using a radioactive monitoring device. Three metabolites were isolated and characterized by silica-gel thin layer chromatography (TLC), gas chromatography-mass spectrometry (GC\MS), and ^{1}H-nuclear magnetic resonance (^{1}H-NMR).

The first metabolite (12%) was 1-hydroxy-4,7,8-TriCDD (Figure 1). GC\MS of the trimethylsilyl (TMS) derivative yielded ions at m/z 374 ($M^{+\cdot}$), 359 ($M-CH_3$), 324 ($M-CH_3$ and Cl). Proton coupling constants (J) reflecting ortho coupling were observed by ^{1}H-NMR {$CDCl_3$: δ=7.14 (s), 7.04 (s), 6.89 (d, J=9.1 Hz), 6.58 (d, J=9.1 Hz)}.

The major metabolite (43%) was 2-hydroxy-1,4,7,8-TCDD (Figure 2). GC\MS of the TMS derivative yielded ions at m/z 408 ($M^{+\cdot}$), 393 ($M-CH_3$), 358 ($M-CH_3$ and Cl). The substitution pattern of the metabolite was confirmed by ^{1}H-NMR comparison with a synthetic sample {CD_3OD: δ=7.23 (s), 7.19 (s), 6.61 (s) ppm}.

The final compound characterized in the hexane extract of the 0-24 h feces was the parent, 1,4,7,8-TCDD (17%)(Figure 3). The 1,4,7,8 substitution was confirmed by ^{1}H-NMR comparison with the authentic dose sample {$CDCl_3$: δ=7.12 (s), 6.95(s) ppm}.

The original hexane extract contained no evidence for parent 1,4,7,8-TCDD by TLC; however, after the extract was allowed to stand refrigerated for several weeks, parent 1,4,7,8-TCDD was detected by a subsequent TLC. This phenomena may be explained by decomposition of a putative arene oxide. Previous studies have shown arene oxides of phenanthrene and naphthalene decompose to the parent aromatics (3). The presence of the metabolites, 1-hydroxy-4,7,8-TriCDD and 2-hydroxy-1,4,7,8-TCDD, indicates that the metabolism of 1,4,7,8-TCDD goes through an oxidation pathway either by direct substitution or through an arene oxide intermediate.

Figure 1

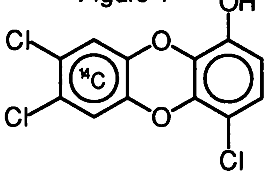


Figure 2

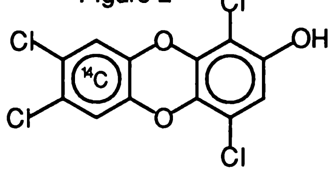
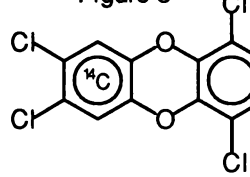


Figure 3



1. Silbergeld, E.K. (1995) Scientific American 48-57.
2. Feil, V.J., et al. (1995) 15th International Symposium on Chlorinated Dioxins and Related Compounds. August 1995, Edmonton, Canada.
3. Feil, V.J., J.K. Huwe, and J.E. Bakke (1986) in Polynuclear Aromatic Hydrocarbons: Chemistry, Characterization and Carcinogenesis, (M. Cooke and A.J. Dennis,eds), pp 893-900, Battelle Press, and references contained in.

NAT2 GENE POLYMORPHISMS IN HUMAN COLORECTAL CANCER AND NON-CANCER SUBJECTS

Shelly L. Satran*, Mark A. Doll, Kevin Gray, and David W. Hein
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Arylamine N-acetyltransferases catalyze the transfer of acetyl groups from the endogenous cofactor acetyl coenzyme A to arylamine (N-acetylation) and hydroxyarylamine (O-acetylation) acceptors. Acetylation is catalyzed by two N-acetyltransferases encoded by *NAT1* and *NAT2* genes. The classical N-acetylation polymorphism results from various *NAT2* alleles producing rapid, intermediate, and slow acetylator phenotypes. It has been shown in some human epidemiological studies that individuals who possess the rapid acetylator phenotype are at an increased risk for the development of colorectal cancer. Our laboratory has recently developed a new method for *NAT2* genotyping which distinguishes between each of the twenty-three *NAT2* alleles that have been identified in human populations. The purpose of this study was to retest this hypothesis using the more powerful *NAT2* genotyping method. Thirty colon samples were obtained from the National Cooperative Human Tissue Network. Twenty colon samples derived from patients diagnosed with colorectal cancer or polyps which are a precancerous lesion, whereas ten colon samples were derived from patients with no evidence of colon cancer (Table 1). DNA was isolated from the colon samples and genotyped for *NAT2* alleles. PCR techniques followed by digestion with various restriction enzymes were used to detect nine separate nucleic acid substitutions in the 870 bp *NAT2* coding region: $G^{191}A$, $C^{282}T$, $T^{341}C$, $A^{434}C$, $C^{481}T$, $G^{590}A$, $A^{803}G$, $A^{845}C$, and $G^{857}A$. The resulting genotypes were used to deduce phenotype as rapid, intermediate, or slow acetylators. Of the nine nucleic acid substitutions, seven appeared in the thirty colon samples tested. There was no apparent correlation between rapid acetylator phenotype and colon cancer incidence (Table 1). There also was no correlation between acetylator phenotype and expression of 2-aminofluorene activity in the colon (Table 2). Further studies should be done using larger numbers of samples. Partially supported by USPHS grant CA-34627.

Table 1. Colon cancer and non-cancer cohorts tested for *NAT2* acetylator genotype

	Cancer	Non-cancer
Total Sample	20	10
Black (%)	5 (25%)	3 (30%)
White (%)	15 (75%)	7 (70%)
Male (%)	16 (80%)	4 (20%)
Female (%)	4 (40%)	6 (60%)
Age Range	40–76	26–85
Age Mean ± S.D.	64.4 ± 8.8	58.9 ± 21.3
Rapid Acetylators (%)	1 (5%)	1 (10%)
Intermediate Acetylators (%)	8 (40%)	3 (30%)
Slow Acetylators (%)	11 (55%)	6 (60%)

Table 2. 2-Aminofluorene N-acetyltransferase activities in colon samples with rapid, intermediate, and slow acetylator genotypes

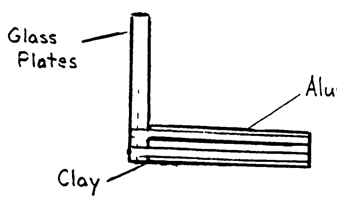
Genotype	N	N-acetyltransferase Activity (nmoles/min/mg)
Rapid	2	310 ± 7
Intermediate	10	270 ± 54
Slow	13	276 ± 43

IMPROVED HOLOGRAPHY TECHNIQUES: OPTIMIZING EXPOSURE TIME TO REDUCE VIBRATION EFFECTS.

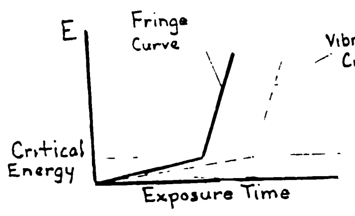
Black Cloud, Randy, R.* and Howell, Francis, L.
University of North Dakota, Grand Forks, ND 58202.

Holograms are formed by recording the phase and amplitude information in the interference patterns of reference and reflected object light (split from a single coherent source), producing fringes in the photographic film. Extraneous vibrations undermine fringe formation in the photochemical emulsion during exposure, inhibiting later holographic image formation. Traditional methods use expensive, high power lasers and bulky vibration dampers (sand boxes, massive tables, inner tubes, etc...) to reduce exposure time and vibration. New techniques, outlined here, use common, inexpensive materials and low power lasers to increase exposure time and eliminate bulky vibration dampers, while reducing the effects of vibrations detrimental to holographic image formation.

Using a 4 mW, HeNe (632.8 nm, random polarization) laser, low sensitivity (200 erg/sq. cm), Agfa 8E75HD (NAH) film[1], two 6" x 6" x 1/4", glass plates, serving as the film holder, were attached at a right angle to a 6" x 6" x 1 1/2", aluminum object platform with a 1/16" layer of oil-based clay and two rubber bands (fig. 1), in an attempt to stabilize the optical path length. The clay/rubber acts as an adhesive, prevents scratching and provides some damping effects, reducing one source of vibration. The law of reciprocity states that any photochemical effect is proportional to the total light energy[2], therefore, fringe development occurs within the emulsion at the time average location of constructive phase interference of the reference beam and reflected object light, where the time average intensity of the light absorbed by the silver halide reaches critical energy, releasing enough silver atoms to form the latent image. At low light levels this effect is weakened, and required exposure time for a given effect increases greatly. Employing reciprocity, short exposures require high energy lasers as vibration duration approach or exceed exposure time to become a major consideration in latent image formation. Alternatively, adjusting beam divergence angles to control and identify optimum exposure time (40 to 60 seconds for 8E75HD) utilizes reciprocity failure phenomena, maintaining the time average intensity contribution from vibrations at undesirable locations with in the emulsion well below the critical energy during the exposure (fig. 2), effectively eliminating the effects of short duration vibrations (relative to exposure time), as long as the vibration amplitude did not permanently alter the optical path length. As exposure time increases further, reciprocity failure becomes undesirable and visible, allowing total light energy contribution from vibration to approach critical energy. Susceptibility to heat (film expansion and temperature gradients) and air currents also become factors in latent image formation as exposure time increases. In later interferometric experiments, the objects were intentionally stressed to produce visible secondary fringes in the resulting holographic image, detecting dislocations of 632.8 nm or 316.4 nm, depending on use of transmission or reflection holograms. Constant object/film distance, optimum exposure times and uniform equipment temperatures, combine to effectively eliminate vibration as a factor in hologram production, allowing greater flexibility in hologram setup configurations on practically any solid surface(s) and encouraging use of safe, low power lasers.



(Fig. 1)



(Fig. 2)

[1] Recommended for both transmission and reflection holograms. Kasper, J. and S. Feller. 198 The Complete Book of Holograms. New York: John Wiley & Sons, Inc..
[2] Saxby, Graham. 1988. Practical Holography. London: Prentice Hall International (UK) Ltd.

Thursday, 25 April

12:00 A TRANSIENT WELLBORE/RESERVOIR MODEL for GAS WELLS
Xiaowei Wang* and A R Hasan
Chemical Engineering, University of North Dakota, Grand Forks

12:20 DEVELOPMENT of a HUMAN *NAT1* GENOTYPE ASSAY: METHODOLOGY and APPLICATION for MOLECULAR EPIDEMIOLOGICAL STUDIES
Anne C Deitz*, Mark A Doll, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

12:40 ADRIAMYCIN-INDUCED OXIDATIVE INJURY and ALTERATION of GLUTATHIONE REDOX CYCLE in the LIVER of MALE and FEMALE MICE
Qiangrong Liang*, Yan Chen, Judith M Alexander, Y James Kang
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

1:00 PROLACTIN-INDUCED EXPRESSION of *bcl-2*, bax, and p53 RAT LYMPHOMA CELLS: RELATIONSHIP to CELL CYCLE PROGRESSION
Matthew A Leff*, Donna J Buckley, Arthur R Buckley
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

1:20 PROCESSED PSEUDOGENES as INTERNAL CONTROLS for PCR: DETECTING MURINE *P53* GEN DELETIONS
Hugh V Nguyen*, Christopher M Weghorst, John W Anderson, Timothy D Rustan, Janis E Hulla
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

break

1:50 SYNTHESIS and STRUCTURAL CHARACTERIZATION of CATIONIC ALUMINUM COMPLEXES WITH POTENTIAL RELEVANCE to LEWIS ACID CATALYSIS
David A Atwood and **Jolin A Jegier***
Center for Main Group Chemistry, North Dakota State University, Fargo

2:10 CLONING, SEQUENCING, and EXPRESSION of *NAT1* and *NAT2* DERIVED from C3H/HeJ (RAPID) and A/HeJ (SLOW) ACETYLATOR INBRED MOUSE STRAINS
Adrian J Fretland*, Mark A Doll, Kevin Gray, Yi Feng, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

2:30 TRANSCRIPTIONAL REGULATION of the HSP RESPONSE in Nb2 LYMPHOMA CELLS
Mingyu Zhang*, Arthur R Buckley, Donna J Buckley, Joshua S Krumenacker, Michael J Blake
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

2:50 INNATE STABILITY COMPARISONS BETWEEN HUMAN, RAT, MOUSE, and SYRIAN HAMSTER RECOMBINANT N-ACETYLTRANSFERASES
Kevin Gray*, Mark A Doll, Adrian J Fretland, Ronald J Ferguson, Timothy D Rustan, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

3:30 FRACTALS in CHEMICAL ENGINEERING: DIFFUSION on FRACTAL LATTICES
Hai Ni*, Douglas Ludlow, Mizuho Schwalm
Chemical Engineering and Physics, University of North Dakota, Grand Forks

3:50 EVALUATION OF *NAT2* POLYMORPHISM in SUSCEPTIBILITY to HUMAN PROSTATE TUMORIGENESIS
Wen Jiang*, Mark A Doll, Anne C Deitz, David W Hein
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

4:10 CLONIDINE INDUCED HEAT SHOCK PROTEIN EXPRESSION in RAT VASCULAR SMOOTH MUSCLE
R J Moen*, Kathy LaVoi and Michael J Blake
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

break

4:40 STEADY-STATE SIMULATION of MULTI PHASE HEAT and FLUID FLOW in GEOTHERMAL WELLS
Peter T Argument* and A Rashid Hasan
Chemical Engineering, University of North Dakota, Grand Forks

5:00 USING PROLACTIN VARIANTS to DISSECT HORMONE-RECEPTOR INTERACTIONS
Joshua S Krumenacker* and Arthur R Buckley
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

5:20 ADRIAMYCIN INDUCED EXPRESSION of ANTIOXIDANTS in the HEART of MICE
Xianhua Yin* and Y James Kang
Pharmacology & Toxicology, UND School of Medicine, Grand Forks

A Transient Wellbore/Reservoir Model for Gas Wells

Xiaowei Wang* and A.R. Hasan
Energy Engineering Ph.D. Program
Department of Chemical Engineering
University of North Dakota
Grand Forks, ND 58202-7101
Tel: (701)-777-3961

When production of fluids occurs from high temperature reservoir, considerable heat exchange takes place between the fluid in the wellbore and its surroundings. This flow condition is further exacerbated in an offshore producing environment when the portion of the wellbore is exposed to the cold seawater. The problem is further complicated if the flow is in unsteady state.

Transient flow of mass, momentum, and energy occurs whenever the coupled wellbore/reservoir system is perturbed. To better understand the mechanism of this transient procedure, transient tests are undoubtedly the best candidates. However, to consider the costs or difficulties in a hostile environment, such as a high pressure and high temperature reservoir, a fully transient wellbore/reservoir simulator is needed. Transient simulations are also very helpful for designing and maintaining pipelines, equipment, and facilities design, particularly in an offshore environment.

In this presentation, we show a hybrid approach to couple the wellbore with the reservoir. The wellbore portion numerically solves the mass, momentum, and energy equations, while the reservoir is handled analytically where single-phase flow occurs. The good agreement between simulation results and testing data has proven the success of the approach.

DEVELOPMENT OF A HUMAN *NAT1* GENOTYPE ASSAY: METHODOLOGY AND APPLICATION FOR MOLECULAR EPIDEMIOLOGICAL STUDIES

Anne C. Deitz*, Mark A. Doll, and David W. Hein
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Aromatic amine carcinogens found in foods, cigarette smoke and the environment can be activated or deactivated by the N-acetyltransferase enzymes, NAT1 and NAT2. Human epidemiological studies suggest an association between the NAT2 acetylation polymorphism and some types of cancers. Recently, an acetylation polymorphism has been established for NAT1, and some alleles have been associated with increased cancer risk (1,2), and so we have developed an efficient method for distinguishing the nine human *NAT1* alleles identified in human populations. Five (*NAT1*3, *4, *5, *10,* and **11*) have been formally named (3) and three others, *SJmt1* and *SJmt2* (4) and *V4* (5) have yet to receive formal names. A ninth *NAT1* allele was recently discovered by our laboratory. The method we have developed utilizes polymerase chain reaction restriction fragment length analysis (PCR-RFLP) to distinguish between each of the eight *NAT1* alleles as shown below.

NAT1 is amplified from genomic DNA using the polymerase chain reaction. The product is then digested with the restriction enzyme *Aat*II to confirm that *NAT1* (and not *NAT2* or *NATP*) has been amplified, and with *Ban*I and *Alw*NI to detect the *NAT1*5* and *NAT1*11* alleles, respectively. The other six human *NAT1* alleles do not contain restriction sites near the known mutation sites. Each of these alleles is distinguished by PCR-RFLP analysis using nested PCR. The *NAT1* PCR product is used in five subsequent PCR amplifications along with primers engineered to contain a partial restriction site. Each of the nested PCR products is then digested with the appropriate restriction enzyme to distinguish the remaining alleles. Whether or not the restriction site will be completed by the template and thus recognized by the restriction enzyme, depends on the presence or absence of the mutation in the template. This method should assist in molecular epidemiology studies investigating genetic predisposition to cancer. Partially supported by USPHS grant CA-34627.

NAT1 allele	Mutation	Restriction site change	Fragment sizes (bp) w/mutation
*NAT1*3*	1095A	deletes *Bsm*A 1	132
*NAT1*4*	1095C	adds *Bsm*A 1	25, 107
*NAT1*5*	$G^{350,351}C$	adds *Ban* I	89, 346, 713
*NAT1*10*	$T^{1088}A$	deletes *Ase* I	96
*NAT1*11*	$T^{640}G$	adds *Alw*N I	241, 402, 505
SJmt1	$G^{560}A$	deletes *Hinf* I	146, 115
SJmt2	$C^{559}T$	adds *Sca* I	117, 21
V4	ff 1091, AAA insertion	deletes *Ase* I	99

1. Bell et al. (1995) *Cancer Research* 55: 3537-3542.
2. Bell et al. (1995) *Cancer Research* 55: 5226-5229.
3. Vatsis et al. (1995) *Pharmacogenetics* 5: 1-17.
4. Hughes and Grant. (1994) *Proc. Tenth Int. Symp. Microsomes Drug Oxidations*, Toronto, p. 278.
5. Vatsis et al. (1994) *Amer. J. Human Genetics* 55(Suppl.): A340.

ADRIAMYCIN-INDUCED OXIDATIVE INJURY AND ALTERATION OF GLUTATHIONE REDOX CYCLE IN THE LIVER OF MALE AND FEMALE MICE

Qiangrong Liang,* Yan Chen, Judith M. Alexander and Y. James Kang
Department of Pharmacology and Toxicology University of North Dakota School of Medicine
Grand Forks, ND 58202-9037

The toxicity of Adriamycin (ADR), a major limiting factor for clinical use of this important anticancer agent, is mediated at least in part by production of reactive oxygen species during its intracellular metabolism.[1] Cardiotoxicity of ADR has been extensively studied. Little is known about ADR hepatotoxicity, although it has been well known that liver is the major metabolic organ of ADR.[2] Glutathione redox cycle including GSH, GSH peroxidase (GSHpx), and GSH reductase (GR) has been implicated to play important role in cytoprotection against ADR-induced oxidative injuries.[3-4] Therefore, the present study was undertaken to determine the effect of ADR on the liver, focusing on oxidative injury and changes in GSH redox cycle.

Male and female FVB mice were treated with ADR at 20 mg/kg by a single ip injection. Four days after the treatment lipid peroxidation in the liver was measured (Table 1). ADR elevated the level of lipid peroxides including malondialdehyde (MDA) and 4-hydroxyalkenals (4-HA) by 46% ($p<0.05$) selectively in the male mouse liver. Alterations of hepatic GSH redox cycle by ADR were compared between male and female mice (Table 1). GR activity was not changed in either male or female liver. ADR decreased GSH concentration by 36% ($p<0.05$) and inhibited the activity of γ-glutamylcysteine synthetase (γ-GCS), the rate-limiting enzyme in *de novo* GSH synthesis by 36% ($p<0.05$) in the male mouse liver only. Northern blot analysis revealed that ADR suppressed the level of mRNA for γ-GCS in the male mouse liver. The activity of GSHpx was depressed by 31% ($p<0.05$) in the male mouse liver, but the level of mRNA for GSHpx was increased in both male and female livers. The results demonstrate that ADR causes oxidative injury more selectively to the male mouse liver. This gender-related oxidative injury correlates with the depressed GSH redox cycle activities, which likely result from the decreased amount of mRNA for γ-GCS, and a post-transcriptional inhibition of GSHpx.

Table 1. ADR-induced lipid peroxidation and alteration of GSH redox cycle in the liver of male and female mice

	Male		Female	
	Control	ADR-treated	Control	ADR-treated
MDA + 4-HA (nmol/g tissue)	79.52 ± 4.48	115.98 ± 7.87*	99.97 ± 8.90	97.12 ± 8.25
GSH-Px (μmol NADPH/mg protein/min)	0.87 ± 0.05	0.60 ± 0.02*	0.86 ± 0.02	0.76 ± 0.03
GR (nmol NADPH/mg protein/min)	30.54 ± 1.37	27.42 ± 0.93	24.53 ± 1.57	24.47 ± 0.63
GSH (μmol/g tissue)	9.26 ± 0.73	5.95 ± 0.52*	9.27 ± 0.53	7.86 ± 0.96
γ-GCS (nmol NADH/mg protein/min)	51.29 ± 2.94	32.85 ± 4.87*	50.80 ± 3.39	47.57 ± 3.10

Values are expressed as mean ± SE. n=8 for each group.
*indicates significant difference between control and ADR-treated groups ($p<0.05$).

1. Keizer HG, Pinedo HM, Schuurhuis GJ and Joenje H (1990). *Pharmacol Ther* **47**:219-231.
2. Carter SK, Adriamycin-a review (1975). *J Natl Cancer Inst* **55**:1265-1274.
3. Babson JR, Abell NS and Reed DJ (1981). *Biochem Pharmacol* **30**:2299-2304.
4. Taylor SD, Davenport LD, Speranza MJ, Mullenbach GT and Lynch RE. *Arch Biochem Biophy* **305**:600-605, 1993.

PROLACTIN-INDUCED EXPRESSION OF *bcl-2*, bax, AND p53 IN RAT LYMPHOMA CELLS: RELATIONSHIP TO CELL CYCLE PROGRESSION

Matthew A. Leff*, Donna J. Buckley, and Arthur R. Buckley
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine
Grand Forks, ND 58202

PURPOSE

Lactogen-dependent Nb2 lymphoma cells represent a useful model for the study of molecular events coupled to prolactin (PRL)-induced proliferation. Moreover, recent evidence has demonstrated the utility of this model for investigation of mechanisms linked to the activation of apoptosis. The present study was conducted to determine whether PRL-stimulated mitogenesis in Nb2 cultures is associated with altered expression of p53, bax, or *bcl-2*; genes which regulate apoptotic mechanisms.

METHODS

Northern Blot Analysis: Total RNA was isolated from 2 x 10^7 Nb2 lymphoma cells cultured in 25-cm^2 culture flasks using RNAzol-B. The RNA was quantitated spectrophotometrically. For Northern analysis, RNA was denatured in formaldehyde and fractionated on 1% agarose gels, then transfered to GeneScreen Plus. Equal loading per lane was verified by ethidium bromide staining of 18S and 28S ribosomal RNA, which was visualized and photographed under UV illumination. The membranes were hybridized with ^{32}P-labeled *bcl-2*, bax, or p53 cDNAs. Immunoblot Analysis: The cells (2.5 x 10^7) were incubated for various time periods after addition of PRL. The cells were rapidly cooled and pelleted by centrifugation. Nb2 cultures were then resuspended in lysis buffer containing: 10 mM Tris-HCl (pH 7.4) at 4° C, 0.15 M NaCl, 5 mM EDTA, 1% Triton X-100, 1 mM PMSF, 25 μg/ml leupeptin, and 25 μg/ml aprotinin. The lysates were centrifuged for 10 min at 14,000 x g at 4° C. Total protein content was determined using the Bradford reagent. Homogenates were fractionated by SDS-PAGE using 10% gels, then electrophoretically transferred to Immunolite blotting membrane. Membranes were blocked overnight at 4° C in 5% nonfat dried milk in Tris-buffered saline. Bcl-2 and Bax proteins were visualized by initially incubating the membranes in the presence of anti-Bcl-2 and Bax polyclonal antibodies (1/100 and 1/1500, respectively) followed by chemiluminescence detection using a secondary antibody coupled to alkaline phosphatase. P53 protein was evaluated by first incubating the membranes in the presence of a specific monoclonal antibody (1/200) followed by chemiluminescence detection as described. The membranes were exposed to x-ray film for 5-15 min.

RESULTS

The addition of PRL (10 ng/ml) to growth-arrested Nb2 cultures rapidly induced three *bcl-2* mRNA transcripts [9.4, 7.3, and 4.2 kilobases (kb)] by 3 h (>15-fold), a time co-incident with early G_1 cell cycle progression. The rapid induction of *bcl-2* mRNA stimulated by PRL was concentration-dependent and not inhibited by cycloheximide, suggesting a direct effect of the hormone. Results from mRNA stability studies indicated that increased expression of *bcl-2* most likely reflects PRL-induced *de novo* transcription rather than enhanced mRNA accumulation. Moreover, PRL-stimulated mRNA transcription was coupled to a parallel increase in Bcl-2 protein (>2-fold) by 6 h. In addition, PRL also significantly enhanced expression of bax and two p53 transcripts (3.8 and 2.2 kb). Maximal expression of each of these genes occured within 8 h (>8-fold), a time associated with late G_1/early S phase. PRL-induced expression of each gene was concentration-dependent. Immunoblot analysis of Bax protein levels following PRL stimulation revealed a 50 % diminution after 2 h compared to controls. The level of Bax expression subsequently increased toward control levels by 8-12 h.

CONCLUSIONS

These results demonstrate that bax, p53, and *bcl-2* mRNAs are expressed in a cell cycle-associated manner subsequent to PRL-stimulation in Nb2 cells. Furthermore, we conclude that *bcl-2* represents an immediate-early gene induced by PRL that may serve an important regulatory function in early G_1 cell cycle progression in this system.

Supported in part by DK44439 from the NIH, RD-383 from the American Cancer Society, and 95B089 from the American Institute for Cancer Research.

PROCESSED PSEUDOGENES AS INTERNAL CONTROLS FOR PCR: DETECTING MURINE *P*53 GEN DELETIONS

Hugh V. Nguyen*, Christopher M. Weghorst, John W. Anderson,
Timothy D. Rustan, and Janis E. Hulla
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Processed pseudogenes share sequence homology with the corresponding functional genes but are sans introns. Gene and pseudogene fragments will co-amplified in polymerase chain reactions when primed from regions of shared homology. The co-amplicons generated from gene and processed pseudogene templates can be distinguished on the basis of size if at least one intron is incorporated into the gene amplicon. We applied these amplification characteristics of the mouse and rat p53 genes and processed pseudogenes to develop a semi-quantitative PCR assay for the detection of *p53* allelic deletions. In the assay, the co-amplicon generated from the endogenous pseudogene template is used as a basis for comparing the yield from the gene template. In this regard, the pseudogene serves as an internal control for the detection of *p53* allelic deletions. DNA from two *p53* knock-out mouse models, each harboring defined *p53* deletions, were used as control templates to show distinction between homozygous and heterozygous gene deletions. This approach is generally applicable to detecting deletions of genes for which there are corresponding processed pseudogenes present in the genome.

SYNTHESIS AND STRUCTURAL CHARACTERIZATION OF CATIONIC ALUMINUM COMPLEXES WITH POTENTIAL RELEVANCE TO LEWIS ACID CATALYSIS

David A. Atwood and Jolin A. Jegier*
Center for Main Group Chemistry, Department of Chemistry, North Dakota State University, Fargo, ND 58105

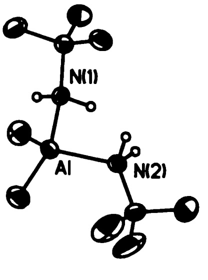
Aluminum complexes have long been used as Lewis acid catalysts in organic reactions such as the polymerization of epoxides and methacrylates (1). To be an effective catalyst, the complex must be electron deficient and/or coordinatively unsaturated. Cationic aluminum complexes are ideal due to their intrinsic electron deficiency. Aluminum cations had been relatively unstudied until we recently developed the [SalenAl(solv)$_2$]X class of complexes (where Salen = N,N'-ethlyenebis(2-hydroxyphenyleneimine), solv = H_2O or MeOH, X = Cl or BPh_4). These complexes were shown to effectively coordinate and oligimerize propylene oxide (2, 3). We have now undertaken a study to understand the factors affecting cationic aluminum complex formation. Herein is reported the preliminary results of the [RR'Al(base)$_2$]X system (where R = alkyl; R' = alkyl or aryloxy; base = H_2N^tBu or (O)PPh_3; and X = Cl or Br).

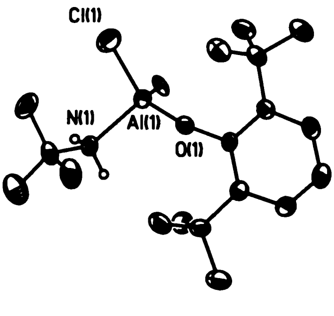
Three factors can affect cation formation in this system: the choice of halide as the anion, the strength of the base used to dissociate the aluminum halide bond, and the nature of the substituents on the aluminum center. The first step was to determine the role of the anion in cation formation. Reaction of Me_2AlX with excess H_2N^tBu led to different products. When X = Cl, only the adduct $Me_2Al(H_2N^tBu)Cl$ was obtained. When X = Br, dissociation of the aluminum-halide bond occurred and the cationic complex $[Me_2Al(H_2N^tBu)_2]Br$ was isolated. The molecular structure of this complex can be seen below. Thus it seems that the demarcation for cation formation is between the relatively hard chloride and relatively soft, polarizable bromide.

The next step was to determine the role of the base. Dissolution of R_2AlX in a weak base such as THF does not lead to cation formation. However, reaction of Me_2AlBr with two equivalents of a stronger base such as $Ph_3P(O)$ leads to the formation of the cationic complex $[Me_2Al((O)PPh_3)_2]Br$. Thus it appears that simple ethers are not strong enough to promote cation formation and that stronger bases such as amines and phosphine oxides are required.

The last factor to be looked at was the affect of the R group on the aluminum center. Reaction of $[Me(PhO)AlCl]_2$ (where PhO = 2,6-di^{t}butylphenoxy) with excess H_2N^tBu leads to the expected adduct $Me(PhO)Al(H_2N^tBu)Cl$. A molecular structure of this complex can be seen below. However, a similar reaction with $[Me(PhO)AlBr]_2$ also leads to an adduct $Me(PhO)Al(H_2N^tBu)Br$ rather than the expected cation. Thus the substitution of an electron donating alkyl group with an electron withdrawing group hinders cation formation. While these reactions did not give the desired cationic products, they did produce compounds with four different groups at the aluminum center. These chiral aluminum centers are of interest due to their rarity in the literature.

In conclusion, we have shown that several factors affect the formation of cationic, organometallic aluminum complexes. The necessary requirements are the use of a relatively polarizable halide, a strong base such as an amine or phosphine oxide, and electron donating substituents on the aluminum center. Future work will include finding bases which are strong enough to displace a chloride as well as a halide from the phenoxy substituted compounds in order to change the electronic and steric properties of the resulting cationic complex. It is also interesting to note that while the six-coordinate complexes mentioned above oligimerize propylene oxide, these four-coordinate complexes do not. Thus, it appears that geometry as well as electronic effects are important in making a catalytically active complex. Future work will also address this issue.





1. Inoue, S. and Aida, T. (1996) Acc Chem Res 29, 1, 39.
2. Atwood, D.A., Jegier, J.A., and Rutherford, D. (1995) J Am Chem Soc 117, 6779.
3. Atwood, D.A., Jegier, J.A., and Rutherford, D. (1996) Inorg Chem 35, 63.

CLONING, SEQUENCING, AND EXPRESSION OF *NAT1* AND *NAT2* DERIVED FROM C3H/HeJ (RAPID) AND A/HeJ (SLOW) ACETYLATOR INBRED MOUSE STRAINS

Adrian J. Fretland*, Mark A. Doll, Kevin Gray, Yi Feng, and David W. Hein
Department of Pharmacology and Toxicology and Surgery
University of North Dakota School of Medicine, Grand Forks, ND 58202

N-Acetyltransferases (E.C.2.3.1.5) catalyze the N- and O-acetylation as well as the N,O-acetylation of aromatic and heterocyclic amine carcinogens. A genetic polymorphism in N-acetyltransferase activity segregates humans into rapid, intermediate, and slow acetylator phenotypes. An acetylation polymorphism also has been described in the mouse (1). To better understand the molecular basis for the acetylation polymorphism in the mouse, amplification primers were designed for mouse *NAT1* and *NAT2* using previously published sequences (1). *NAT1* and *NAT2* from C3H/HeJ(rapid) and A/HeJ(slow) acetylator inbred mice were amplified by polymerase chain reaction, and cloned into the plasmid vector pUC19 and transformed into DH5α competent *E. coli*. After sequencing both *NAT1* and *NAT2* from both strains, they were subcloned into a prokaryotic expression system using pKK223-3 as the vector, and JM105 competent *E. coli*. Both *NAT1* and *NAT2* are encoded for by an 870 bp nucleotide sequence in both humans and mice as well as other mammals. The nucleotide sequence of *NAT1* did not differ between the rapid and slow acetylator inbred strains. This sequence was identical to that of the BALB/c inbred mouse (2). *NAT2* differed between the rapid and slow acetylator mice at a single nucleotide with an A to T transition at nucleotide number 296. This base substitution caused an amino acid substitution of asparagine to isoleucine at position 99. This confirmed the *NAT2* sequence of other inbred strains of mice (1). Recombinant NAT2 proteins derived from rapid and slow acetylator mice readily catalyzed N-acetyltransferase activity, and did not differ in their substrate specificity, expression of immunoreactive protein or electrophoretic mobility in Western Blot analysis, or Michaelis-Menten kinetics. The recombinant NAT2 proteins did differ significantly in their intrinsic stability. The slow acetylator NAT2 was much less stable than corresponding NAT2 from rapid acetylator mice. These findings are consistent with results previously described with other inbred mice using eukaryotic expression systems (1) and is one basis for the polymorphism in N-acetyltransferase activity in mice. The recombinant proteins of NAT1 from rapid and slow acetylators did not differ in their substrate specificity, intrinsic stability or, Michaelis-Menten kinetics. Therefore NAT1 has little effect in the polymorphic N-acetyltransferase activity seen in mice. Partially supported by USPHS grants CA-34627 and USEPA grant R-821836.

1. Martell, K.J., Vatsis, K.P., Weber, W.W. (1991) *Mol. Pharmacol.* 40: 218-227.
2. Kelly, S.L. and Sim, E. (1994) *Biochem. J.* 302: 347-353.

Transcriptional Regulation of the HSP response in Nb2 Lymphoma Cells

Mingyu Zhang*, Arthur R. Buckley, Donna J. Buckley, Joshua S. Krumenacker
and Michael J. Blake
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine
Grand Forks, ND 58202

BACKGROUND: Virtually all cells respond to heat stress by increased expression or induction of one or more highly conserved cellular stress response proteins termed, heat shock proteins (HSPs). However, in previous experiments, we showed that exposure of Nb2-11 cells, a PRL-dependent cell line, to heat stress (41° C for 1 hr) did not result in expression of inducible HSP70, a response common to other cell culture and tissue systems. Furthermore, the level of constitutive HSP70 and HSP90 actually declined due to the heat exposure. In contrast, SFJCD1 cells, a PRL-independent cell line, expressed inducible HSP70 upon heat shock and maintained a stable expression of constitutive HSP70 and HSP90 in response to the same exposure. This unusual heat-stress response of Nb2-11 cells appears to involve a defect in HSP transcriptional regulatory mechanisms that is restored or partially restored by pretreating the cells with PRL.

PURPOSE: Based on these studies, we hypothesized that reduced constitutive HSP70 expression is attributed to altered transcriptional regulation or lower mRNA stability and that heat labile heat shock transcription factor (HSF) is responsible for the absence of inducible HSP70 expression. In this report, these hypotheses are addressed by identifying factors that contribute to alterations of HSF and the mechanisms whereby PRL restores the HSP response in Nb2-11 cells.

METHODS AND RESULTS: Sodium butyrate (NaBT) transforms Nb2-SFJCD1 cells from a hormone-independent to a hormone-dependent phenotype and makes them sensitive to apoptosis induced by dexamethasone. HSF fragmentation in NaBT-treated Nb2-SFJCD1 cells was determined by immunoblotting using an antibody specific to HSF1 to further investigate the mechanism(s) contributing to the regulation of inducible HSP70. Similar to Nb2-11 cells, fragmented HSF was observed in NaBT-treated SFJCD1 cells after heat stress. This fragmentation corresponded with a lack of inducible HSP70 expression in these cells. However, constitutive HSP70 mRNA expression was not reduced by heat stress. Nb2-11 cells were treated with cycloheximide and protease inhibitors to determine whether heat-induced HSF fragmentation was due to a specific protein factor. Cycloheximide did not affect the heat shock response of Nb2-11 cells at the mRNA level. The protease inhibitors PMSF, TLCK, and TPCK did not restore a normal heat shock response in these cells. Nb2-11 cells were treated with cycloheximide just prior to a 6hr PRL exposure to determine whether newly synthesized proteins contributed to the protective effects of PRL. Unexpectedly, cycloheximide blocked PRL-induced expression of constitutive HSP70 mRNA transcripts thereby abrogating the effects of PRL to prevent the heat-induced decline in the HSP response.

CONCLUSIONS: These results demonstrated that NaBT treatment may activate a protease that degrades HSF. The fact that cycloheximide treatment prior to heat stress did not affect the heat shock response of Nb2-11 cells suggest that proteases responsible for HSF fragmentation are not newly synthesized. Furthermore, this protease activity was not reversed by several serine-protease inhibitors although other proteases may be involved. Apparently, protein synthesis is required for PRL-induced increases in constitutive HSP70 expression, however, it is unclear how PRL protects the heat shock response in Nb2-11 cells. Results of this study describe unique HSP regulatory events in Nb2-11 cells, possibly a common characteristic of other hormone-dependent tumors.

INNATE STABILITY COMPARISONS BETWEEN HUMAN, RAT, MOUSE, AND SYRIAN HAMSTER RECOMBINANT N-ACETYLTRANSFERASES

Kevin Gray*, Mark A. Doll, Adrian J. Fretland, Ronald J. Ferguson,
Timothy D. Rustan, and David W. Hein, Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

One of the most interesting aspects of N-acetylation is the existence of a genetic polymorphism in the rate of acetylation which means that humans and rodents can be classified as slow, intermediate, or rapid acetylator phenotypes. N-, O-, and N,O-acetyltransfer reactions are catalyzed by two N-acetyltransferase isozymes NAT1 and NAT2. In human epidemiological studies, slow acetylators show a higher incidence of urinary bladder cancer while rapid acetylators show a higher incidence of colon cancer. To better understand the molecular basis of the acetylation polymorphism, rapid and slow acetylator human, rat, mouse, and Syrian hamster NAT1 and NAT2 encoding alleles were cloned and expressed in a prokaryotic expression system. The recombinant N-acetyltransferases were compared for innate stability following incubation at 50 degrees celsius (Table 1). When comparing the inactivation rate constants of the human NAT2 allozymes, some NAT2 proteins were less stable than NAT2 4 which is associated with rapid acetylators. In particular, NAT2 7A, 7B, 14A, 14B, 14C, and 18 were significantly less stable than NAT2 4. Although human and rodent NAT1 and NAT2 allozymes share high nucleotide and deduced amino acid sequence homologies, nevertheless significant differences were observed in the intrinsic stabilities of the recombinant proteins. Rapid (NAT2 15) and slow (NAT2 16A) acetylator hamster NAT2 were more stable than rapid (NAT2 20) and slow (NAT2 21A, 21B) acetylator rat NAT2. Rapid (NAT2 8) acetylator mouse NAT2 was stable, but slow (NAT2 9) acetylator mouse NAT2 was 10-fold less stable. Human NAT2 4 was more stable than any of the recombinant rodent NAT2 allozymes. In contrast, human NAT1 was less stable than human NAT2 and all rodent (NAT1 6, mouse; NAT1 8, 9; Syrian hamster; NAT1 13, rat) NAT1 allozymes. Rat NAT1 4 was the most stable of all NAT1 and NAT2 proteins. These results suggest that stability differences in NAT1 and NAT2 contribute to both acetylator genotype and species dependent differences in acetyltransferase activity. Partially supported by USPHS grant CA-34627 and USEPA grant R-821836.

Heat Inactivation Rates for Recombinant Acetyltransferases

NAT2 Allozyme	Species	N	First Order Inactivation Rate Constant (hr^{-1})
NAT1 4	Human	1	34.0 ± 2.46
NAT1 6	Mouse	4	10.5 ± 0.2
NAT1 8	Hamster (R)	4	25.1 ± 5.0
NAT1 9	Hamster (S)	4	24.6 ± 8.1
NAT1 13	Rat	4	0.133 ± 0.011
NAT2 4	Human	4	1.14 ± 0.10
NAT2 8	Mouse (R)	4	3.48 ± 0.416
NAT2 9	Mouse (S)	4	35.6 ± 3.3
NAT2 15	Hamster (R)	4	5.64 ± 0.67
NAT2 16A	Hamster (S)	5	5.48 ± 0.56
NAT2 20	Rat (R)	4	26.3 ± 4.1
NAT2 21A	Rat (S)	3	35.9 ± 4.2
NAT2 21B	Rat (S)	3	43.2 ± 8.9

Fractals in Chemical Engineering: Diffusion on Fractal Lattices

Hai Ni*, Douglas Ludlow, Mizuho Schwalm[(#)]
Department of Chemical Engineering,
University of North Dakota, Grand Forks, ND 58203-7101

The mathematical concepts of fractal geometry has been applied in recent years to various areas of chemical engineeing, such as adsorption and catalysis, chemical kinetics, transport phenomena, and polymerization[(1)]. We use the Vicsek Lattice[(2)] as an ordered model for fractal aggregates to study diffusion of mass and energy on lattices. The transport equation on Vicsek Lattice is built by a renormalization analysis, which is different from previously studied lattice models due to the special neighbours and boundry conditions. Transport calculations can be made with the recursion equation by use of Fortran and Mathematica. This method forms lattices that lead to exact solution of the differential diffusion equations. The lattice space is well defined mathematically using fractal geometry, yet has the heterogeneous complexity of a " real " system. The application and experimental process of the model is being considered in the department of chemical engieering at UND.

(1). G. Biardi, M. Giona and AR. Giona, eds.: Chaos and Fractals in Chemical Engineering (1995)

(2). Tamas Vicsek, Fractal Growth Phenomena (Second Edition), 1992.

(#): Department of Physics, UND

EVALUATION OF *NAT2* POLYMORPHISM IN SUSCEPTIBILITY TO HUMAN PROSTATE TUMORIGENESIS

Wen Jiang*, Mark A. Doll, Anne C. Deitz, and David W. Hein
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Prostate cancer incidence has increased and has become the second leading cause of cancer deaths in U.S. males. The etiology of prostate cancer is not known, but environmental and hormones factors are almost certainly involved. DNA damage from environmental carcinogens has been regarded as a critical initiating step in carcinogenesis. These carcinogens undergo metabolic activation to electrophilic metabolites that bind DNA or protein and form DNA-, and protein-carcinogen-adducts which initiate tumorigenesis. N-Acetyltransferases (NAT2 and NAT1) are involved in the metabolic activation of aromatic and heterocyclic amine carcinogens as they catalyze N-acetylation, O-acetylation and N,O-acetylation in human and other mammalian species. Human capacity to acetylate aromatic amines is subject to a genetic polymorphism which segregates individuals into rapid, intermediate, or slow acetylator phenotypes. Twenty-three polymorphic N-acetyltransferase (*NAT2*) alleles have been identified in human populations. mRNA expression of *NAT2* gene has been observed in the human prostate. Analysis of DNA-adducts from prostate biopsies of human prostate cancer patients revealed the presence of multiple DNA adducts (1). Therefore, the metabolite activation of chemical carcinogens within the prostate may determine sensitivity of this target organ in humans and the *NAT2* polymorphism may contribute to susceptibility of human prostate cancer. Our hypothesis is that *NAT2* genotype may be a risk factor in the etiology of human prostate tumorigenesis. To test this hypothesis, we obtained a cohort of 38 prostate samples from the Cooperative Human Tissue Network of the National Cancer Institute. Nineteen of the samples were from patients with documented prostate cancer, while the other nineteen were obtained from patients with documented benign prostatic hypertrophy (BPH). The ages of the prostate cancer cohort ranged from 51 to 73 years for a mean $\pm$ S.D. of 63.6 $\pm$ 6.0 years. The ages of the BPH cohort ranged from 59 to 89 years for a mean $\pm$ S.D. of 72.8 $\pm$ 8.6 years. Both cohorts consisted of seventeen Caucasian- and two African-Americans. DNA obtained from the prostate samples was amplified by the polymerase chain reaction and tested for *NAT2* genotype using a recently published method (2). Deduced acetylator phenotypes differed significantly ($p<0.05$) between the prostate cancer and BPH groups. The percentage of rapid/intermediate/slow acetylator phenotypes was (10.5%/47.4%/42.1%) in the prostate cancer patients and (5.3%/21.1%/73.7%) in the BPH patients. Statistical analysis of this data suggests that rapid acetylator phenotype confers a relative risk factor of 1.89 (confidence interval 0.99 to 3.60) and an odds ratio of 3.85 (confidence interval 0.98 to 3.60) for prostate cancer. These results will be tested further in a cohort of 400 patients with prostate cancer or BPH and suggest that rapid *NAT2* genotype is a risk factor for prostate cancer incidence analogous to colorectal cancer incidence in humans. This work was partially supported by USPHS grant CA-34627.

---

1. Hein, D.W., Doll, M.A., Wood, D.P. Jr., Gupta, R.C., and Spencer-Beach, G.G. (1996) Effect of acetylator genotype on DNA adduct levels in human prostate cancer biopsies. *Proc. Amer. Assoc. Cancer Res.* 37: in press.
2. Doll, M.A., Fretland, A.J., Deitz, A.C., and Hein, D.W. (1995) Determination of human *NAT2* acetylator genotype by restriction fragment length polymorphism and allele-specific amplification. *Anal. Biochem.* 231: 413-420.

Clonidine Induced Heat Shock Protein Expression In Rat Vascular Smooth Muscle

R.J. Moen*, Kathy LaVoi, and Michael J. Blake
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine
Grand Forks, ND 58202

BACKGROUND

Restraint-stress and the administration of phenylephrine, an α_1-adrenergic receptor agonist, have been previously shown to induce expression of the 70kd heat shock protein (HSP70) in the aorta. This response could be blocked by the α_1-selective antagonist prazosin, suggesting HSP70 induction in the aorta was mediated by activity at α_1-adrenergic receptors. However, we have determined that clonidine, an α_2-adrenergic receptor agonist and effective antihypertensive, also induces the HSP response in this tissue.

PURPOSE

The objective of this study was to characterize the physiologic and cellular mechanisms supporting clonidine-induced HSP expression in the aorta. To address this objective we determined the kinetics of clonidine-induced HSP70 mRNA and protein expression in the aorta, identified the molecular mechanisms involved in the induction of HSPs, and assessed the pharmacologic and physiologic specificity of the clonidine-induced HSP response with respect to receptor and tissue types.

METHODS & RESULTS

In dose response experiments, animals were administered clonidine in 0.05, 0.1, 0.5, and 1.0 mg/kg i.p. injections. Northern analysis revealed a dose-dependent increase in HSP70 mRNA levels. The time course for clonidine-induced HSP70 expression was determined in the aorta at 1, 2, 4, and 6 hrs after drug administration by Northern and Western analysis, respectively. Messenger RNA levels peaked at 1 hr while protein levels peaked after 2 hrs. Clonidine-induced HSP expression was not restricted to the HSP70 family as HSP89α, 89β, 60, and 27 were also induced. Gel mobility shifts were used to determine if HSF was activated by the administration of clonidine. Animals were treated with saline or clonidine (0.5 mg/kg) and killed after 0, 15, 30, 45 , 60 min. Protein from individual aortas were incubated with radiolabeled HSE then separated on a polyacrylamide gel. No HSF binding activity was visible in any of the protein samples taken from drug-treated aortas, however binding was visible in heat-stressed controls. The specificity of clonidine's effects was assessed using selective pharmacologic agents. Yohimbine (α_2-specific antagonist; 2.5 mg/kg i.p.) and prazosin (α_1-specific antagonist; 1 mg/kg i.p.) blocked HSP70 mRNA expression. Nifedipine (Ca^{2+}-channel blocker; 15 mg/kg i.p.) blocked clonidine's action while mecamylamine (ganglionic blocker; 0.5 mg/kg i.p.) and reserpine (catecholamine depletor; 5 mg/kg/day i.p.) had no effect. Clonidine-induced HSP70 expression was determined in liver, brain, brown fat, kidney, skeletal muscle, heart, lung adrenal gland, and aorta. After i.p. administered of 0.5 mg/kg clonidine the only tissues showing a significant HSP70 mRNA induction were the lung, adrenal gland, and aorta.

CONCLUSIONS

The dose-response and time course data suggest that the HSP response is related to the actions of clonidine in the aorta. Based on results from administration of pharmacologically selective agents, clonidine's ability to induce an HSP response is apparently specific to the α_2-adrenergic receptor and separate from that responsible for activation by phenylephrine or restraint. Induction of other HSPs indicates that clonidine has the ability to initiate the general induction of many or all HSP families. However, the lack of HSF binding activity suggests clonidine initiates transcription of these genes by unique regulatory mechanisms. The results of this study characterize a model system where the HSP response is evoked by a specific pharmacologic agent and may aide in the development of treatment strategies that selectively target HSP expression *in vivo*.

Steady-State Simulation of Multiphase Heat and Fluid Flow in Geothermal Wells

Peter T. Argument* and A. Rashid Hasan
Department of Chemical Engineering
University of North Dakota
Grand Forks, ND 58201-7101

Petroleum companies have long performed multiphase flow analysis to determine characteristics of downhole conditions in crude oil reservoirs where crude oil, natural gas, and water are present or where gas injection is utilized to provide artificial lift. The transition to the use of multiphase flow studies to the analysis of geothermal wellbores has recently begun to provide analysis of geothermal reservoirs for alternative energy production.

Multiphase flow in wellbores is defined as the cocurrent flow of more than one phase in horizontal and inclined systems. Unlike single phase flow, in a multiphase flow system the two or more fluids compete for available flow area which increases the complexity of the fluid flow analysis. It becomes necessary to evaluate parameters such as the Flow Patterns, In-situ Velocity, and Void Fraction in order to accurately simulate the system. Once a reliable model has been developed of the steady state condition then the system can be run through simulations of shut-in tests to analyze downhole conditions of the reservoir.

This thesis will concentrate on analysis and performance evaluation of a FORTRAN simulator developed solely for modeling a geothermal wellbore and reservoir system. Development of the model will begin with the design of a steady state fluid flow system, and have additional aspects such as heat transfer and wellbore insulation characteristics built into it. The end result will be a model that can accurately simulate steady-state flow for a geothermal well. Once an accurate model has been developed, it will be tested to determine the dependency of the production characteristics on initial conditions such as insulation, wellbore diameter, and production time.

Using Prolactin Variants to Dissect Hormone-Receptor Interactions

Joshua S. Krumenacker* and Arthur R. Buckley
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine
Grand Forks, ND 58202-9037

Prolactin (PRL)-dependent Nb2 lymphoma cells have proven to be invaluable for the study of signal transduction and molecular events coupled to lactogenic-hormone/receptor activation. Thus, PRL stimulation of proliferation in this model has recently been shown to be coupled to rapid activation of the serine/threonine kinase, mitogen-activated protein kinase (MAPK) and JAK2, a receptor-associated tyrosine kinase, in a manner similar to growth hormone (GH). Importantly, PRL and its receptor each share significant sequence homology with GH and the GH receptor. Recent studies of GH action have indicated that upon binding to its receptor, the hormone provokes receptor dimerization as an initial step, ultimately leading to a cellular response. Molecular/genetic analysis of GH has revealed the presence of two receptor binding regions within the hormone, sites 1 and 2, located within helices 1 and 3, respectively. The homology between PRL and GH, as well as with their respective receptors, provides important insight into mechanisms involved in hormonal action common to both pituitary polypeptides. Therefore, whether PRL, similar to GH, requires a two binding site interaction to stimulate a cellular response was investigated utilizing several PRL variants. A glycosylated form of equine PRL (G-ePRL, obtained from G.R. Bousfield and V.Y. Butnev, Wichita, KS), which contains a bulky carbohydrate moiety within helix 1 and a mutant form of bovine PRL (G129R met-bPRL, obtained from P. Gout and M. Smith, Vancouver, BC), which contains a glycine to arginine substitution in helix 3 were used. Glycosylated ePRL possesses an alteration in putative receptor binding site 1 while G129R met-bPRL is mutated within the binding site 2 domain. These reagents were utilized to investigate hormone-receptor interactions as well as signal transduction processes linked to PRL-stimulated mitogenesis.

In initial experiments, the mitogenic potency of each PRL variant was evaluated by determining cell population density as well as ^{3}H-thymidine incorporation into DNA subsequent to hormonal stimulation in lactogen-dependent Nb2 cells. Stimulation of stationary cells with both forms of ePRL evoked a concentration-dependent increase in cell population and ^{3}H-thymidine incorporation. However, G-ePRL was approximately 10-fold less potent as a mitogen compared to its nonglycosylated counterpart. The putative binding site 2 mutant, G129R met-bPRL, was found to be devoid of mitogenic activity while the wild-type hormone was highly effective as a concentration-dependent mitogen. These results suggest that functional binding sites 1 and 2 are most likely required for full cellular activation of Nb2 cell proliferation by PRL.

In other experiments, each of the PRL variants were evaluated for their capacity to activate MAPK and JAK2 kinase. The activity of each of these kinases is regulated by phosphorylation on tyrosine residues; therefore, augmented tyrosyl phosphorylation can be utilized as an index of enzyme activation. Employing immunoblot analysis using antiphosphotyrosine monoclonal antibodies, it was determined that oPRL, bPRL, as well as G129R met-bPRL each enhanced tyrosyl phosphorylation of MAPK within 10 minutes when added to stationary Nb2 cultures. Tyrosyl phosphorylation of MAPK in G-ePRL-treated cells was substantially less compared to ePRL. Finally, results from preliminary experiments suggest that increased tyrosyl phosphorylation of JAK2 occurs within the identical time period in Nb2 cells incubated with oPRL, bPRL, and G129R met-bPRL. Together, these results demonstrate that: (1) mutation of receptor binding sites 1 and 2 within PRL markedly reduce or nullify PRL-stimulated Nb2 cell proliferation and (2) functional inactivation of binding site 2 has no effect on PRL-stimulated tyrosyl phosphorylation of signalling kinases. We conclude that an event(s) temporally downstream from tyrosyl phosphorylation of either MAPK or JAK2 is responsible for the inability of G129R met-bPRL to stimulate proliferation in Nb2 lymphoma cells. This work was supported in part by grants from the U.S. Public Health Service (DK44439), the American Cancer Society (RD-383), and the American Institute for Cancer Research (95B089).

ADRIAMYCIN INDUCED EXPRESSION OF ANTIOXIDANTS IN THE HEART OF MICE

Xianhua Yin and Y. James Kang
Department of Pharmacology and Toxicology, University of North Dakota,
School of Medicine, Grand Forks, ND 58202

Adriamycin (ADR) is a highly effective anticancer drug. However, its full clinical potential has been limited by severe cardiotoxicity. The biochemical mechanism of ADR cardiotoxicity remains unknown, one of the leading hypothesis is the involvement of reactive oxygen species in the cardiac damage (1). Therefore, endogenous antioxidant defenses are expected to be important determinants of myocardial ADR tolerance. Recent research had found that the biosyntheses of DNA, RNA and protein were markedly decreased by ADR when compared with other tissues (2). Whether this inhibition by ADR has a global effect on the antioxidant genes is not clear. The effects of ADR on cardiac antioxidant defense at both protein and gene levels may underlie the mechanism for ADR cardiotoxicity. Therefore, we determined the effect of ADR on antioxidant enzyme activities and the levels of mRNA transcripts for antioxidants.

FVB mice (7 weeks old) were treated with ADR (15 mg/kg, ip), and the control mice received an equal amount of saline. On the fourth day of postdosing, mice were sacrificed and hearts were collected for the analyses of enzyme activities and mRNA transcripts. Activities of catalase, glutathione peroxidase (GSH-Px), glutathione reductase (GSH-Rd), superoxide dismutase (SOD) and γ-glutamyl cystene synthetase (γ-GCS) were determined; and levels of metallothionein (MT) protein and glutathione (GSH) were measured. Transcription of these antioxidant genes was also analyzed by Northern Blot from the total RNA extracted from the heart.

ADR caused significant increase in MT mRNA levels of both male and female mice with much stronger induction for male than female. Catalase and SOD-I mRNAs were also elevated in both male and female, similar to the pattern of MT mRNA, with lower induction in female mice. In accordance with the enhanced mRNA levels of MT and catalase, the enzyme activity of catalase was enhanced by ADR, while MT protein level was markedly increased with a stronger response in male than female mice. γ-GCS activity was significantly enhanced in both male and female mice (Table 1). No significant difference was observed for GSH-Px and GSH-Rd in either enzyme activities or mRNA levels.

Table 1. ADR-induced alterations of antioxidants in the heart of mice

	Male		Female	
	Control	ADR-treated	Control	ADR-treated
Catalase (μmol H_2O_2/mg protein/min)	23.35 ± 1.69	36.78 ± 0.75	22.28 ± 5.28	38.01 ± 15.31*
GSH-Px (nmol NADPH/mg protein/min)	53.9 ± 15	47.1 ± 6	56.5 ± 11	61.8 ± 1
GSH-Rd (nmol NADPH/mg protein/min)	4.7 ± 0.06	4.7 ± 0.04	4.8 ± 0.02	5.0 ± 0.05
γ-GCS (μmol NADH/mg protein/min)	0.111 ± 0.09	0.206 ± 0.03*	0.123 ± 0.02	0.202 ± 0.04*
MT (μg/g heart)	16.25 ± 4.19	60.41 ± 13.1*	18.51 ± 2.77	31.60 ± 5.86*

Values expressed as mean ±SD for 2-3 mice.
* indicates significant difference between control and ADR-treated groups ($p<0.05$).

These results suggest that although ADR has a global inhibitory effect on the syntheses of DNA, RNA and protein in the heart, it selectively enhances the activities of antioxidant systems. This enhancement most likely results from up-regulation of gene expression.

1. V. Lee, A.K. Randhawa and P.K. Singal (1991). Am. J. Physiol. 161:H989-H995.
2. Y. Sazuka, H. Tannizawa and Y. Takino (1989). Jpn. J. Cancer Res. 80:1000-1005

Thursday, 25 April

12:50 STRATIGRAPHY of the SENTINEL BUTTE FORMATION (PALEOCENE) at the ASH COULEE QUARRY, BILLINGS COUNTY, NORTH DAKOTA

John S Post*, J Mark Erickson, John W Hoganson
Geology, St Lawrence University, Canton, NY and
North Dakota Geological Survey, Bismarck

1:10 OCCURRENCE and TAPHONOMY of the TRIONYCHOID TURTLE *PLASTOMENUS* from the ASH COULEE QUARRY, SENTINEL BUTTE FORMATION (PALEOCENE), BILLINGS COUNTY, NORTH DAKOTA

Glen B Kays*, J Mark Erickson, John W Hoganson
Geology, St Lawrence University, Canton, NY and
North Dakota Geological Survey, Bismarck

1:30 PALEOENVIRONMENT INTERPRETATIONS from FOSSIL *METASEQUOIA* ? STUMPS in the PALEOCENE SENTINEL BUTTE FORMATION at ASH COULEE, BILLINGS COUNTY, NORTH DAKOTA

Andrew F Hill*, J Mark Erickson, John W Hoganson
Geology, St Lawrence University, Canton, NY and
North Dakota Geological Survey, Bismarck

1:50 STRATIGRAPHY and PALEONTOLOGY of the PIERRE SHALE (CAMPANIAN), COOPERSTOWN SITE, GRIGGS COUNTY, NORTH DAKOTA

John W Hoganson*, Michael Hanson, Dennis L Halvorson, Verla Halvorson
North Dakota Geological Survey, Bismarck, and Griggs County Historical Society, Cooperstown

2:10 PALEOBIOLOGY and STRATIGRAPHY of *PANOPEA OCCIDENTALIS* in LIFE POSITION in the FOX HILLS FORMATION (LATE CRETACEOUS: MAASTRICHTIAN) of NORTH DAKOTA

J Mark Erickson* and Brett D Palmateer
Geology, St Lawrence University, Canton, NY

2:30 PALEOENVIRONMENTAL INTERPRETATIONS of the BULLHEAD LITHOFACIES (CRETACEOUS: MAASTRICHTIAN) IRON LIGHTNING MEMBER, FOX HILLS FORMATION BASED on PHYSIL MINERALOGY

Peter W Connett* and J Mark Erickson
Geology, St Lawrence University, Canton, NY

2:50 PHYSIOGRAPHIC PROVINCES of NORTH AMERICA'S CENTRAL REGION

Eric N Clausen*
Midcontinent Institute, Minot State University, Minot

3:30 SMALL MAMMAL COMMUNITY STRUCTURE of a WESTERN MINNESOTA GRAVEL QUARRY

Jacquie R Gerads*, Lowell E Schmitz, Mickie L Dik, Donna M Bruns Stockrahm
Biology, Moorhead State University, Moorhead, MN

3:50 EVALUATION of the USE of RADIOTELEMETRY as a TOOL for MONITORING MOVEMENTS of NORTHERN GRASSHOPPER MICE in WESTERN MINNESOTA
Jamie L Steggeman*, Bryan K Watters, Lowell E Schmitz, Jacquie R Gerads, Donna M Bruns Stockrahm

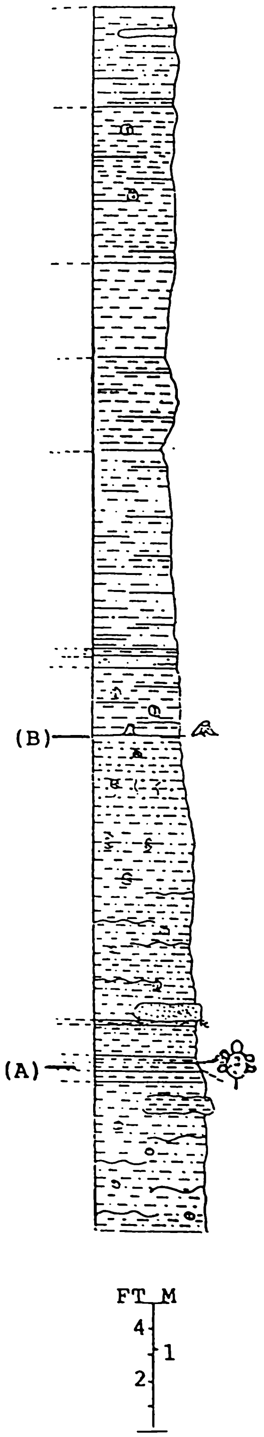
4:10 USE of FLY ASH in HIGH-FLEXURAL-STRENGTH CERAMICS
Diane K Ingvalson* and Bruce A Dockter
Energy & Environmental Research Center, Grand Forks

4:30 BIOTIC RESOURCES of the GREAT PLAINS: SERVING INFORMATION on the INTERNET
Douglas H Johnson*, Terry L Shaffer, Shane C Erstad, Lawrence D Igl, Diane L Larson
National Biological Service, Northern Prairie Science Center, Jamestown

4:50 STATE OF SCIENCE EDUCATION REFORM in NORTH DAKOTA
Debra Tomanek*
Botany/Biology, North Dakota State University, Fargo

STRATIGRAPHY OF THE SENTINEL BUTTE FORMATION (PALEOCENE) AT THE ASH COULEE QUARRY, BILLINGS COUNTY, NORTH DAKOTA

John S. Post[1],* J. Mark Erickson[1], John W. Hoganson[2]
[1]Department of Geology, St. Lawrence University, Canton, NY 13617
[2]North Dakota Geological Survey, 600 E. Boulevard Ave, Bismarck, ND 58505



In the summer of 1995, under permit from the U.S. Forest Service, we began examination of an important Paleocene paleontological site. This site, here termed the Ash Coulee Quarry, is located in Billings County, North Dakota (Sec. 27, T. 142 N., R. 100 W.). This study is meant to provide control for fossiliferous units at the site and to provide sedimentalogical and paleoenvironmental information. The 31.1 m composite section detailed here was measured with standard jacob's staff, hand level, and Brunton compass techniques. Five sections, producing a stratigraphic fence around the site, were measured to supply details of facies change within the local region.

Lithologies represented at this site include siltstones and claystones, sandstones, buff shales, and thin beds of lignite typical of the Sentinel Butte Formation in many areas. Thick gray shales, often with "popcorn" weathering textures, predominate in the section, but noteworthy occurrences of trough cross-stratified, light beige, fine-grained, partially indurated sandstones serve as bench forming units in the local physiography. These sandstones appear to represent point bar deposition in a large river floodplain, in an upper delta platform setting. Two such units form lenses locally, one is more than a meter thick and crops out ten meters south of the Ash Coulee Quarry site. This lens diminishes to 0.3 meters at the line of section measured at the site. This sandstone displays large scale planar cross-strata separated rhythmically by very thin clay partings. The top of the composite section consists of a very light, whitish or yellowish, siltstone that is an obvious cap rock on the buttes of the area.

Specific beds of interest are a fissile, gray carbonaceous shale containing turtle remains (A) and an horizon of silicified *Metasequoia* ? stumps (B) indicated on Figure 1. The 10 to 15 cm-thick turtle fossil-bearing shale bed is poorly indurated and overlies a brown organic-rich shale. Together these persist across the area at horizon (A), and at the Ash Coulee Quarry site they contain abundant well-preserved turtle remains. Shells of freshwater mollusks, carbonized logs and other vertebrate remains (fish, champsosaur crocodile and salamander) are also present. The turtles from this bed are the focus of work reported by Kays, et al (1).

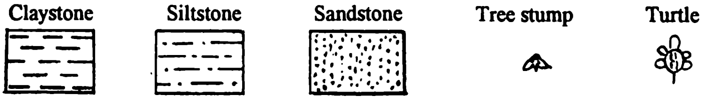
Horizon (B) is a prominent bench-forming lignitic claystone and siltstone containing *in situ* silicified *Metasequoia* ? stumps. This bed is interpreted to be a paleosol (2) within the Sentinel Butte Formation and is the focus of another study (3). This stratigraphic framework suggests that the Ash Coulee Quarry is in the lower portion of the Sentinel Butte Formation.

The authors wish to acknowledge the U. S. Forest Service, Custer National Forest, and the Clay Banyai family for assistance with this research endeavor.

---

1. Kays, G. B., Erickson, J. M., Hoganson, J.W., 1996, (This volume).
2. Fastovsky, D.E., and McSweeney, K., 1987, Geological Society of America Bulletin , v.99 p.66-77.
3. Hill, A.F., Erickson, J.M., Hoganson, J.W., 1996, (This volume).

LEGEND



OCCURRENCE AND TAPHONOMY OF THE TRIONYCHOID TURTLE *PLASTOMENUS* FROM THE ASH COULEE QUARRY, SENTINEL BUTTE FORMATION (PALEOCENE), BILLINGS COUNTY, NORTH DAKOTA

Glenn B. Kays[1],* J. Mark Erickson[1], and John W. Hoganson[2]
[1]St. Lawrence University, Canton, New York 13617
[2]North Dakota Geological Survey, 600 E. Boulevard Ave., Bismarck, N.D. 58505-0840

Field work conducted during the summer of 1995 in the Paleocene Sentinel Butte Formation at the Ash Coulee Quarry (1) of Billings County, North Dakota, resulted in the discovery of more than a dozen specimens of a freshwater turtle belonging to the Superfamily Trionychoidea. Material reported here includes: 2 skulls, one nearly complete, one partially complete; 3 complete plastrons, and 3 essentially complete carapaces all presumed to be adult. A variety of limb bones occur but have not been analyzed as yet. Based on carapace ornament, lack of protruding ribs at the shell margins, and presence of a sutured plastron lacking fontanels, we are assigning the material to the genus *Plastomenus* (Cope, 1873). This is the largest assemblage of plastomenid remains recorded to date, and is the first record of skulls in association with complete dorsal and ventral shells.

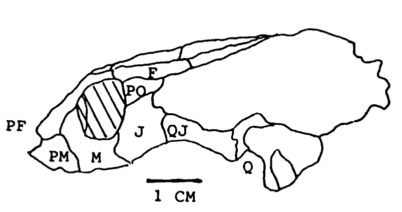
Morphological comparisons with related fossil, and living turtle taxa support the uniqueness and validity of the Plastomenidae (Hay, 1908). Skull comparisons (with several genera of the Family Trionychidae) result in the following: Our specimens of *Plastomenus* differ from the Epifamily Kinosternoidae because in the Kinosternoidae the frontal makes no contribution to the orbital, whereas in our material there is a substantial frontal contribution; our specimens differ from the Cretaceous *Adocus* (Family Trionychidae) because in *Adocus* the premaxillary is more blunt, and the zygomatic arch is curved in the shape of an hourglass, whereas the premaxillary in *Plastomenus* is smaller and its suture with the prefrontal slopes much more gradually; our plastomenid skulls are one half the size of those of *Aspideretes* species; and finally, our *Plastomenus* specimens differ from *Khunnuchelys* in that the jugal of our specimen contributes to the orbital. There is only one other *Plastomenus* skull (*P. Insignis*) described in the literature. That skull was assigned to *Plastomenus* on the basis of its association with a few plastomenid shell fragments. It differs markedly from our specimens. The dimensions of our most complete skull are: 77 mm long and 50 mm wide at the zygomatic arch. Figure 1a and b illustrate the unrestored skull which is slightly compressed in the nasal region.

The following measurements were obtained from post cranial material: carapace length along the neural axis 280 mm to 228 mm; width perpendicular to the neural axis 260 mm to 240 mm; plastron length along the medial suture (including the entoplastron) 191 mm to 168 mm; width along the hyo-hypoplastral suture 264 mm to 236 mm.

This is a very unusual assemblage because the turtles occur as complete, but slightly disarticulated, carapaces and plastrons scattered among lignified logs in a 10 to 15 cm-thick bed consisting of poorly indurated, gray shale. The cause of death of these turtles is not known, but it was a significant event to the population. Comparisons with studies made by Brand (2) suggest that turtle carcasses in a lacustrine setting begin to disarticulate after 12 days, and float for up to 45 days. Limb bones, claws, and disarticulate skulls are scattered among the shells, but none is fully articulated, indicating that the carcasses began to disarticulate before arriving at the site of deposition and continued to do so after arrival where they sank at varying times. Presence of logs suggests dead turtles floated into a log jam in an oxbow, or clay-bottomed lake setting, collected there and disarticulated. Gentle currents may have subsequently disturbed the remains slightly but most sorting was pre-settling.

---

1. Post, J.S, et al., 1996, Stratigraphy of the Sentinel Butte Fm. (Paleocene) at the Ash Coulee Quarry, Billings County, North Dakota. (This volume.)
2. Brand, L., 1995, Personal Communication. Loma Linda University. Loma Linda, California.



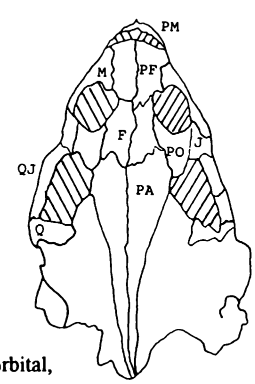


Fig. 1 (a&b) Left lateral, and top views of *Plastomenus* sp. skull specimen. Drawings by Caren Quinn

Key to Figure: PM-Premaxillary, MX-Maxillary, PF-Prefrontal, F-Frontal, PO-Postorbital, J-Jugal, QJ-Quadratojugal, PA-Parietal, Q-Quadrate.

PALEOENVIROMENT INTERPRETATIONS FROM FOSSIL *METASEQUOIA* ? STUMPS IN THE PALEOCENE SENTINEL BUTTE FORMATION AT ASH COULEE, BILLINGS COUNTY, NORTH DAKOTA.

Andrew F. Hill[1]*, J. Mark Erickson[1], and John W. Hoganson[2]
[1]Department of Geology, St. Lawrence University, Canton, New York 13617
[2]North Dakota Geological Survey, 600 E. Boulevard Ave., Bismarck, ND 58505-0840

Thirty-nine silicified stumps thought to belong to *Metasequoia* ?, found during excavation at the Ash Coulee Site (1), in Billings County, North Dakota, provide insights to the paleoenvironment of the Williston Basin during the Paleocene. The stumps are exposed at two localities on the same bedding plane developed on a lignite or lignitic shale interpreted to represent a paleosol. Most are in original growth position. Measurements of stump height, width, tree rings, root orientations, and stump distribution allow the reconstruction of a portion of this paleoforest.

Siltstones and claystones of the Sentinel Butte Formation have been recognized as flood basin deposits on a large delta plane (2). The Ash Coulee Forest was a warm temperate forest living in and on the margins of a large swamp. Tree rings have been examined both on the stumps and in thin section. The presence of the growth rings indicates the trees were living in a temperate climate, the narrow late wood indicates an abrupt end to seasons (3).

Growth ring data were collected from 16 stumps by counting rings exposed in weathered portions of the stump tops. By establishing rings per cm of individual trees and multiplying by the radius, a surrogate value, referred to here as "age", can be estimated. Forty-three root buttress orientations were taken from 13 stumps. Roots from both sites show a preferred orientation of 80° to 200°.

A relationship between average "age" and stump height can be established between the two sites. At site AFH 95-13-1/28 the mean average tree "age" is 1230 and has a height of 21.3 cm. The average tree at site AFH 95-13-A/J has an "age" of 631and has an average height of 38.1 cm providing an age gradient for the paleoforest. This difference in the "age" and height between the two sites has taphonomic implications. It appears the forest was riparian or paludal and the preservation of stumps was a function of submergence. The "age" gradient suggests directional "younging" of the forest towards the northeast perhaps the direction of the swamp or embayment around which the forest grew. Death of the forest, if it was a catastrophic event, seems to have occurred simultaneously throughout as rising water, sediment deposition, or both, encroached on the lowland holding the trees. Water logged portions of the trees, usually the drowned root systems, were preserved to the height they were saturated. Slope of the paleolandscape can be approximated by the gradient of stump heights measured in this study. Stump heights increase to the northeast suggesting this was the down-slope direction on the paleosol surface. Thus the "younger" trees bordered the swamp or bay that lay on the north-east margin of this forest. Slope gradient was 3.8 mm per meter.

Distances between stumps, when compared with stump size, allow some interpretations of canopy width and extent of cover in this ecosystem. No undisputed evidence of fire data was noted and an absence of insect borings supports the interpretation that preservation occurred under aqueous conditions.

---

1. Post, J.S., Erickson, J.M., and Hoganson J.W., 1996, Stratigraphy of the Sentinel Butte Formation (Paleocene) at the Ash Coulee Quarry, Billings County., North Dakota. This volume.

2. Jacob, A.F., 1976, Geology of the upper part of the Fort Union Group (Paleocene), Williston Basin, with reference to uranium. North Dakota Geological Survey Report of Investigation 58, 49 p.

3. Parrish, J. T., and Spicer R.C.A., 1988, Middle Cretaceous wood from the Nanushuk Group, central North Slope, Alaska. Palaeontology, v. 31, pt. 1, p. 19-34.

STRATIGRAPHY AND PALEONTOLOGY OF THE PIERRE SHALE (CAMPANIAN), COOPERSTOWN SITE, GRIGGS COUNTY, NORTH DAKOTA

John W. Hoganson[1*], Michael Hanson[2], Dennis L. Halvorson[2], Verla Halvorson[2]
[1]North Dakota Geological Survey, 600 East Blvd., Bismarck, North Dakota, 58505-0840
[2]Griggs County Historical Society, P. O. Box 242, Cooperstown, North Dakota, 58425

One of the thickest and best exposed outcrops of the Pierre Shale in eastern North Dakota occurs along the Sheyenne River valley, 8.5 km southeast of Cooperstown, Griggs County. Four and a half meters of the Gregory Member of the Pierre Shale is overlain by 37.5 m of the DeGrey Member of the Pierre Shale at this site. The upper 24 m of DeGrey is obscured by vegetation and glacial drift containing large erratics. The contact between the two members is sharp and possibly unconformable. The Gregory Mbr. consists of highly fossiliferous (invertebrates), light brown to tan, calcareous claystone. Yellowish-brown ironstone concretions occur in this member. The DeGrey Mbr. is a light to dark gray, noncalcareous shale. One to three cm thick beds of very light gray bentonite occur throughout the DeGrey Mbr. but are more common in the lower 6 m of the unit. The basal 6 m of the DeGrey is lighter colored than above because of the bentonite. Black, iron-manganese carbonate and light gray, phosphatic concretions are common in the lower part of the member. These concretions are often fossiliferous containing fragments of *Inoceramus* and other invertebrates.

A diverse invertebrate fossil assemblage is found in the Gregory Member including: Protozoa (foraminifera), Coelenterata (*Micrabacia*), Bryozoa, Brachiopoda (*Lingula*), Scaphopoda (*Dentalium*?), Bivalvia (*Inoceramus, Nucula, Nuculana, Pteria, Nemodon*?, oysters), Gastropoda (*Margaritella, Trachytriton, Atira, Oligoptycha, Graphidula*?), Cephalopoda (*Baculites gregoryensis*, *Didymoceras cochleatum*, *Didymoceras* sp., *Solenoceras mortoni*, *Jeletzkytes*?), Annelida?, Arthropoda (*Dakoticancer, Callianassa, Hoploparia*), Asteroidea, and Echinoidea (*Eurysalenia*). The cephalopods are typical of the *Baculites gregoryensis* western interior ammonite zone and indicate a middle Campanian age. Sparse shark teeth (*Carcharias*) are the only vertebrate fossils found in the Gregory Mbr. at the Cooperstown site. It is assumed that the DeGrey Member at this site is also Campanian in age but no age diagnostic fossils were recovered from that member.

An assemblage of vertebrate fossils occurs in the basal 7.5 m of the DeGrey Member at this site. The remains, mostly teeth and vertebrae, of eight mosasaurs have been found at this stratigraphic level over an area of about 0.5 square km. Two mosasaur taxa, *Plioplatecarpus* and mosasaurinae sp., have been identified from these remains. What appears to be a nearly complete skeleton of *Plioplatecarpus* was found at an elevation of 1295' and is currently being excavated. The shark taxa, *Squalicorax pristodontus, Cretolamna appendiculata, Pseudocorax, Carcharias*, and *Squalus*, represented by isolated teeth, are found at this stratigraphic level. Several teeth of *Squalus* were found in close proximity (within millimeters) of a coracoid and mandible of the *Plioplatecarpus* skeleton. Teeth of the enchodontid fish *Enchodus*, isolated vertebrae and other teleost remains, and a tarso-metatarsal of the hesperornithid bird *Hesperornis regalis* were also recovered from this level.

We gratefully acknowledge the Orville Tranby and Tim Soma families for allowing us access to this important fossil site.

PALEOBIOLOGY AND STRATIGRAPHY OF *PANOPEA OCCIDENTALIS* IN LIFE POSITION IN THE FOX HILLS FORMATION (LATE CRETACEOUS: MAASTRICHTIAN) OF NORTH DAKOTA.

J. Mark Erickson* and Brett D. Palmateer
Geology Department, St. Lawrence University, Canton, NY 13617

In 1972, a field party working under NSF-URP grant GY-9761 to the senior author examined a stratigraphic section in the Fox Hills Formation of northern Sioux County, North Dakota, in which a significant number of the bivalve mollusk *Panopea occidentalis* Meek and Hayden were preserved in life position. Speden (1), when revising the Fox Hills Bivalvia, found *P. occidentalis* to be rare, and presented data from only four specimens ranging in length from 31.5 to 93.5 mm. He noted that this species is "..restricted to the *Tancredia-Ophiomorpha* Biofacies and the Irish Creek lithofacies where Waage found specimens in life position." (1.-p.138). No indication is given of the location of that site. Fossils in life position offer an important opportunity to evaluate parameters of both paleobiology and deposition that are otherwise unavailable. Their occurrence is noteworthy.

Exposed in a vertical array in an 8-meter-long cutbank of very fine, unindurated sandstone of the Timber Lake Member were a number of unusual concretionary sandstone columns cemented by iron oxide and calcium carbonate. Concretions terminate upward at an abrupt erosional disconformity upon which a coarser sandstone was deposited. In the base of each concretion was a well-preserved specimen of *P. occidentalis*. Fresh specimens possessed all shell material including the conchiolin and calcium carbonate portions of the ligament, whereas weathered specimens left well-preserved molds. The outcrop provided a cross-sectional, linear sampling transect through this preserved population allowing measurement of size distribution data from 53 specimens.

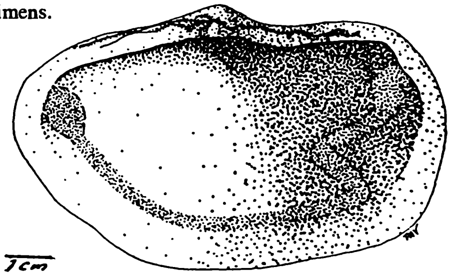


Figure 1.-- View of the interior of a right valve of *Panopea occidentalis*.

The following dimensions were recorded: max. length (n=41) 91.4 mm; min. length 45.1 mm; max. height (n=52) 56.9; min. height 26.4 mm; range of posterior gape (n=42) 10.8 to 34.2 mm; range of pallial sinus depth (n=30) 15.4 to 29 mm; and number of major growth bands 7? to 16. Data indicate that this population was bimodal in size distribution with peaks in the 55 to 64 mm and 75 to 84 mm length size classes. Gerontic individuals exceeded 85 mm in length whereas there do not appear to be juveniles preserved. In transect *P. occidentalis* was seen to live between 12.7 and 35.5 cm apart. Minimum depth of burial for these clams, which had the longest siphons of any Fox Hills bivalve, was 25.4 cm below the disconformity truncating the concretions. We interpret the concretions to represent mucous-lined siphonal tubes cemented early (2) after death came to the population by rapid entombment under the confining bed. Prior to death a storm surge removed significant sediment from the tidal flat behind the barrier bar (3) in which these clams lived. No other infaunal organisms are preserved beneath the disconformity, indicating their removal by scour prior to deposition of the coarser sandstone which fills some concretion cores. Several specimens have Fe-rich cemented masses in the position of the visceral mass. Circumstances suggest rapid burial and death of the adult population in which the feet were atrophied making escape impossible. Individuals <45 mm in length, including all juveniles, lived more shallowly and were scoured away. *P. occidentalis* individuals are found in storm deposits with *T. americana* and *Dosiniopsis deweyi* on the Timber Lake barrier bar (4) indicating that storm waves had scoured more than 25 cm, likely more than 50 cm, of sand to exhume them from their infaunal habitat.

Sedimentologic analysis shows the habitat to have been 88.9% sand, 7.9% silt and 3.2% clay by weight (5). Comparing this with Speden's information (1) indicates a stratigraphic position in the Timber Lake Member that appears to be lateral to the upper portion of the Irish Creek lithofacies of Waage. Such relationships have been difficult to trace from South Dakota into North Dakota, making this rare preservation both stratigraphically and paleobiologically important.

The senior author gratefully acknowledges the field acumen of Mr. Douglas E. O'Brien and art of Pamela Vogan.

1. Speden, I.G. 1970, Yale Peabody Museum Bulletin 33, 222p. 2. Carpenter, S.J., J.M. Erickson, and M.R. Owen. 1988. Jour. Sed. Petrology, v. 58, no.4, p.706-723. 3. Erickson, J.M. *In* Erickson, J.M. and J.W. Hoganson. 1992. N. D. Geol. Surv. Misc. Ser. 76, p.199-241. 4. Bailey, L.T., and J.M. Erickson. 1973. The Compass, v.50, no. 2, p.23-37. 5. Peters, C.S. 1975. Paleoautecology of seven species of Bivalvia (Mollusca) from the Timber Lake Mem. of the Fox Hills Fm. (U. Cret.). Unpub. B.S. Thesis, St. Lawrence University, Canton, N.Y., 44p.

PALEOENVIRONMENTAL INTERPRETATIONS OF THE BULLHEAD LITHOFACIES (CRETACEOUS: MAASTRICHTIAN) IRON LIGHTNING MEMBER, FOX HILLS FORMATION BASED ON PHYSIL MINERALOGY.

Peter W. Connett[1*] and J.M. Erickson[2]
[1]82 Judson Street, Canton, N.Y. 13617
[2]Geology Department St. Lawrence University, Canton, N.Y. 13617

In the summer of 1993, the Late Cretaceous (Maastrichtian) Fox Hills Formation was sampled with emphasis on the Bullhead lithofacies in the Iron Lightning Member of North Dakota. Samples were processed and analyzed to identify the dominant suite of <5μm physils (clay minerals) using X-ray diffraction. Physils represented in this size fraction are illite/smectite, illite, 12.4A° smectite, authigenic and detrital chlorite and kaolinite. Detrital kaolinite, which was identified when the amount rose above 2% of the total, was found only in the Bullhead and Colgate lithofacies. Chlorite/smectite, a mixed-layered physil was also identified, as was the zeolite clinoptilolite. The suite of minerals in the Iron Lightning Member differed measurably from samples of the Pierre Shale and the Trail City and Timber Lake Members of the Fox Hills Formation, mainly by the presence of detrital kaolinite and chlorite.

Results from a quantitative interpretation of the physils present, using methodology of Schultz (1) show a kaolinizing trend of the Bullhead lithofacies, with the highest percentage of kaolinite occurring in the Colgate. The influx of chlorite and kaolinite in the Bullhead verifies a closer proximity to the terrestrial (Hell Creek) environment as suggested by the work of Parham (2), Weaver (3), and Debrabant (4). This rise in kaolinite corresponds with a coarsening trend in the sediments from the prograding Fox Hills-Hell Creek delta. Beside chlorite and kaolinite no trends in the other physils were observed (Figure one).

Presence of chlorite/smectite, illite, *Crassostrea glabra* and overall low percentages of authigenic and detrital kaolinite suggest temperate conditions on the cool side and/or rapid weathering and erosion.

The Bullhead lithofacies as a back-barrier lagoon, brackish swamp and/or interlobe basin has been suggested by prior research (5,6) and is supported by its physil suite. Working from Kosters (7) modeling of the Barataria interlobe basin of the Mississippi and on the basis of physil content, an occurrence of the oyster *C. glabra*, and textural and lateral variation of sediments, it is determined that the Bullhead lithofacies is comprised of three named subfacies: deep estuarine fill, back-bar lagoonal platform and overbank fill. Incipient swamp sediments where found and are included in the overbank fill subfacies.

The Bullhead physil lithofacies are poorly developed on the Cedar Creek anticline. Further east into the distal coastal plain of the Fox Hills Seaway of Sioux and Emmons Counties, in and north of the type area, the Bullhead lithofacies is well developed and well exposed where estuarine coastal morphology existed due to deltaic coalescing and closure of the Fox Hills Seaway in a barrier island-lagoonal setting..

1. Shultz, L.G. 1964. Quantitative interpretation of mineralogical composition from X-ray and chemical data for the Pierre Shale. Geological Professional Paper, 391-C.
2. Parham, W.E. 1963. Lateral clay mineral variations in certain Pennsylvanian underclays. Twelfth National Conference on Clays and Clay Minerals: Clay and Clay Minerals, Pergamon Press, 581-601.
3. Weaver, C.E. 1989. Clays, Muds and Shales. Elesvier Science Publishers. 819p.
4. Debrabant, P., N. Fagel, H. Chamley, V. Bout and J.P. Caulet. 1993. Neogene to Quaternary clay mineral fluxes in the Central Indian Basin. Palaeo., Palaeo., Palaeo, 103:117-131.
5. Palubniak, D.S. 1972. Paleoecology of Upper Cretaceous oysters in the Fox Hills Formation, North Dakota, and comparisons with recent oyster ecology. Unpubl. M.S. thesis. Kent State Univ. 119p.
6. Erickson, J.M. 1992. Subsurface stratigraphy, lithofacies and paleoenvironments of the Fox Hills Formation...North Dakota Geo. Survey Misc. Series 76:199-241.
7. Kosters, E.C. 1989. Organic-clastic facies relationships and chronostratigraphy of the Barataria interlobe basin, Mississippi delta plain. Jour. of Sed. Pet., 59(1):93-113.

Physiographic Provinces of North America's Central Region

Eric N. Clausen
Midcontinent Institute, Minot State University, Minot, ND 58707

North America's central region physiographic provinces are redefined here in an effort to better understand glacial history.

Midcontinent Trench: The Midcontinent Trench is defined as the 2000-kilometer long and 100-kilometer wide through valley which extends from Alberta to eastern Iowa. Northwest-southeast oriented Missouri Escarpment segments in Saskatchewan and North Dakota and the northeast flank of Minnesota's Prairie Coteau serve as the Trench's southwest wall. Northeast wall remnants include Minnesota's stagnation moraines; North Dakota's Turtle Mountains; and Saskatchewan's Moose Mountains, Touchwood Hills, and Last Mountain. Midcontinent Trench drainage networks, which include the North Saskatchewan, Qu'Appelle, Souris, James, Sheyenne, Minnesota, and Cedar Rivers, formed when a large southeast-oriented river (named the *Midcontinent River*) was dismembered and most water diverted to the northeast.

Midcontinent Trench System: The Midcontinent Trench is linked to other through valleys, including a north-south oriented valley between the Missouri Escarpment and Prairie Coteau (*Dakota Trench*), a north-south valley between the Pembina Escarpment and Minnesota stagnation moraines (*Agassiz Trench*), a northwest-southeast valley between the Eagle and Thickwood Hills (*North Saskatchewan Trench*), a northwest-southeast valley between the Thickwood and Thunder Hills (*Cowan Lake Trench*), a north-south valley between the Thunder and Cub Hills (*Montreal Lake Trench*), and a northeast-southwest valley between the Cub-Wapawekka and Pasquia Hills (*Saskatchewan Trench*). These and other through valleys link the Midcontinent Trench with Hudson Straits (northeast) and the Rocky Mountain Trench (west). The Dakota Trench served as the Midcontinent River's west distributary (*Dakota River*) and is linked to the Lower Missouri Valley while the east distributary is linked to the Upper Mississippi. The Trench System (except the Dakota Trench) was initiated by Midcontinent River tributaries which later reversed flow direction and dismembered the Midcontinent River.

Midcontinent Moraine: Midcontinent Trench System through valleys isolate moraine-covered uplands which are collectively named the Midcontinent Moraine. The Midcontinent Moraine includes Minnesota stagnation moraines; North Dakota's Turtle Mountains; Manitoba's Riding and Duck Mountains and Porcupine Hills; Saskatchewan's Moose Mountains and Pasquia, Touchwood, Thickwood, Mostoos, Beaver, Thunder, Eagle, Cub, and Wapawekka Hills; and Alberta's Birch and Pelican Mountains and Caribou, Cameron, Swan, Saddle, Naylor, Hawk, Whitemud, Clear, Birch, and Buffalo Head Hills. These moraine-covered uplands remain because supraglacial meltwater rivers sliced down into the continental ice sheet to form ice-walled and bedrock-floored trenches which isolated intervening ice sheet masses.

Southwest Moraine: The Southwest Moraine is the nearly continuous glacial drift deposit located immediately south and west of the Midcontinent Trench and which extends in a northwest-southeast direction from the Canadian Rockies to the Mississippi Valley. The Southwest Moraine includes the Prairie Coteau and Missouri Coteau and is crossed in the Dakotas by only the south-flowing James River, in Saskatchewan by only the north-flowing South Saskatchewan River, and in Alberta by only the north-flowing North Saskatchewan and Athabasca Rivers. The Southwest Moraine formed when the supraglacial Midcontinent River cut an ice-walled and bedrock-floored trench which detached the continental ice sheet's southwest margin, forming an independent, northwest-southeast oriented ice sheet (*Southwest Ice Sheet*).

Southwest Trench: The Southwest Trench is immediately south and west of the Southwest Moraine and extends from the Mississippi Valley to the Rocky Mountains in northwest Wyoming, Montana, and Alberta. The Southwest Trench includes the Lower Missouri Valley and extends westward between the Pine Ridge Escarpment and Southwest Moraine. The Southwest Trench surface is broken by Rocky Mountain outliers including the Black Hills and Bighorn, Crazy, Snowy, and Belt Mountains. Southwest Trench drainage networks, which include the Cannonball, Cheyenne, Powder, Wind-Bighorn, Yellowstone, Musselshell, and South Saskatchewan Rivers, formed when a large southeast-oriented river (*Southwest River*) was dismembered and water diverted to the northeast. The poorly defined Southwest Moraine-Southwest Trench boundary resulted because the Southwest River eroded deeply into the Southwest Ice Sheet margin.

Great Divide Surface: South and west of the Southwest Trench is the Great Divide Surface which follows the east-west continental divide from the Canadian Rockies to Mexico. In Montana and the Canadian Rockies the Great Divide Surface is characterized by linear mountain ranges and valleys. Further south, the Teton, Wind River, Uinta, Sierra Madre, Medicine Bow, Laramie, and other mountain ranges rise above the Surface. Great Divide Surface drainage networks formed when a large north-south oriented river (*Great Divide River*), which originated in northwestern Canada, was dismembered by Rocky Mountain uplift, with water diverted to both sides of the present-day continental divide.

Interpretation: The above landforms evolved during rapid meltdown of North America's only Cenozoic continental ice sheet. The Great Divide River formed when a supraglacial river crossed the ice sheet margin in northwestern Canada and flowed south—the Rocky Mountains did not exist when the meltdown began. The Great Divide River was dismembered when rapid erosion and accompanying redeposition, combined with ice sheet weight, destabilized the continent's isostatic equilibrium and caused Rocky Mountain uplift. The Southwest River next formed along the ice sheet's southwest margin. At the same time the ice sheet's southwest margin was raised, trapping meltwater on the ice sheet surface, and forming the supraglacial Midcontinent River which flowed parallel to the ice sheet margin. When the Midcontinent, Dakota, and Southwest Rivers had eroded the Mississippi and Lower Missouri Valleys headward into Minnesota and South Dakota respectively, the ice sheet had thinned sufficiently that the Midcontinent River was dismembered. Midcontinent River dismemberment and crustal warping then caused the Southwest River to be dismembered as its water broke through the Southwest Ice Sheet barrier. Unstable climates, caused by Rocky Mountain uplift and drainage reversals, several times briefly revived the melting ice sheets and account for small-scale ice-formed features found on the Midcontinent Trench System floor and walls, blockages of northeast-oriented drainage routes which caused the Missouri Valley to form, and Rocky Mountain and Cordilleran glaciation—the Rocky Mountains did exist when the meltdown ended.

SMALL MAMMAL COMMUNITY STRUCTURE OF A WESTERN MINNESOTA GRAVEL QUARRY

Jacquie R. Gerads*, Lowell E. Schmitz, Mickie L. Dik, and Donna M. Bruns Stockrahm
Department of Biology, Moorhead State University
Moorhead, MN 56563

Small mammals, mainly rodents and shrews, are often a forgotten part of grassland habitats. The small mammal community composition is important for many reasons. Rodents are often the base of the food pyramid for raptors and large mammals. Rodents can serve as indicators of the health and balance of the grassland ecosystem as well as influence the vegetation in an ecosystem by being prime movers of the energy flow from plants to animals.

As part of a larger study, 4 study plots in Clay County, Minnesota, were live-trapped for small mammals during the summer of 1995 with emphasis on community structure in a western Minnesota gravel quarry. The quarry consisted of open, sandy areas with interspersed grasslands. We implemented a 10-by-10 trapping grid scheme with 10 m between traps along a transect and 10 m between transects. Three of the plots were in close proximity to each other, while the fourth plot was approximately 300 m away. A total of 100 Sherman live-traps were used per plot, each baited with peanut butter, rolled oats, and/or canned dogfood. Trapping efforts varied somewhat, but traps were generally set at sunset and checked beginning at sunrise for 4 consecutive days. Animals were trapped on Plots 1, 2, and 3 in June and on Plot 4 in August. Plot 2 was resampled in August. The following information was collected on each captured small mammal: species, sex, age, weight, reproductive condition, location of capture, and habitat. Each animal was toe-clipped for individual identification and then released at the capture location.

The following data are for all 4 plots combined. A few of the animals were captured on more than 1 plot but are only counted once in the totals. Meadow voles (Microtus pennsylvanicus) (n = 72, 35 males, 37 females) were the most abundant, followed by deer mice (Peromyscus maniculatus) (n = 46, 23 males, 21 females, 2 unknown sex). Prairie voles (Microtus ochrogaster) were less common than meadow voles (n = 15, 6 males, 9 females). Both meadow voles and prairie voles were associated with vegetation dominated by grasses with an accompanying relatively thick grass litter layer. Meadow jumping mice (Zapus hudsonius) (n = 16, 5 males, 11 females) were not exceedingly dense but were captured on all 4 study plots. Northern grasshopper mice (Onychomys leucogaster) (n = 2, 1 male, 1 female) were trapped on only 1 plot and were associated with sparsely vegetated hillocks. We defined "hillocks" as the sandy spoil piles scattered around the quarry presumably made by previous excavation activities. Two of each of the following species were also captured: arctic shrews (Sorex arcticus) (2 females), masked shrews (S. cinereus) (2 females), short-tailed shrews (Blarina brevicauda) (1 female, 1 sex unknown), thirteen-lined ground squirrels (Spermophilus tridecemlineatus) (1 male, 1 female), and Franklin's ground squirrels (S. franklinii) (sex unknown). The shrews were associated with disturbed soils and the ground squirrels with dense ground cover. Small mammal diversity was quite high at this gravel quarry, probably due in part to the great heterogeneity of the habitat.

We gratefully acknowledge the financial support of the Minnesota Chapter of The Nature Conservancy, the Minnesota Nongame Wildlife Tax Checkoff, and the Reinvest in the Minnesota Program through the Minnesota Department of Natural Resources, Section of Wildlife, Natural Heritage and Nongame Research Program. We also thank the Moorhead State University (MSU), the MSU Foundation, and the Zoological Society of Minnesota for financial assistance.

EVALUATION OF THE USE OF RADIOTELEMETRY AS A TOOL FOR MONITORING MOVEMENTS OF NORTHERN GRASSHOPPER MICE IN WESTERN MINNESOTA

Jamie L. Stegeman*, Bryan K. Watters, Lowell E. Schmitz, Jacquie R. Gerads, and Donna M. Bruns Stockrahm
Department of Biology, Moorhead State University, Moorhead, MN 56563

This study was part of a larger study of northern grasshopper mouse (Onychomys leucogaster) ecology in western Minnesota. Our main objective for this portion of the study was to establish habitat use and movement patterns by using various techniques, with emphasis placed on the use of radiotelemetry. The study site was located in Clay County, MN (T141N, R46W, S36), in a gravel quarry characterized by scattered hillocks. We defined "hillocks" as the scattered, sandy spoil piles presumably made by previous excavation activities. Small mammals were live-trapped to locate northern grasshopper mice (NGM) during June and August 1995. An adult male was finally captured on a hillock on 17 August 1995. Subsequent trapping located an additional 2 adult male and 2 adult female NGM. Four of the 5 mice were also powdertracked (1). Periodic trapping was conducted to further monitor movements. Two NGM (1 male - 26 g; 1 female - 27 g) were radiocollared (SOM 2028 MVS XMTR; frequency 150.944 MHz and 151.727 MHz; Wildlife Materials, Inc.) with collars weighing 2 g each. Tracking was done using a TRX-2000S radioreceiver with a 3-element folding Yagi antenna (Wildlife Materials, Inc.).

Radiotelemetry indicated that NGM seemed to prefer the hillocks in which to make their tunnel systems. Weedy species were often common on the hillocks. NGM seemed to prefer an open habitat, at least at the base of the plants, in which to maneuver. During the day, the male remained inactive in burrows that were built within hillocks that were less than a meter high to those that were several meters high. This male had a large home range, with approximately 1 km between distant points. Evidence of pair bonds was found. Fluorescent powder trails indicated that the radiocollared male and female used the same trail system and entered the same burrow. Radiotelemetry positions on the night of 18 August indicated that they were hunting together. The NGM seemed to use the sandy, flat stretches between hillocks as hunting grounds at night.

Securing the radiocollars to the NGM was difficult, partly due to the design of the collar. The transmitter and battery were held on the mouse by the antenna which encircled the mouse's neck. The antenna ends were inserted into a metal sleeve (5mm x 1.5mm) which was then crimped to hold the ends in place. Due to the width of even a small pair of pliers, it was difficult to get a secure crimp and a proper fit. The battery life was supposedly 60 days, but an erratic signal was emitted from the male's collar in less than a month. The signal from the female's collar was undetectable after approximately 24 hr. When she was recaptured 2 days after being collared, she no longer had her collar, possibly due to a poor initial fit. In future studies, we would like to test a collar with a different method of attachment to the mouse.

In spite of the difficulties in the design of the radiocollar attachment, radiotelemetry holds promise as a method to study movements of a species with a large home range, such as the NGM, because the chances of retrapping these animals are small if they leave the study plot. Powdertracking is useful to detect short-range movements, but the powder wears off over longer distances.

We are grateful for the financial support from the Minnesota Chapter of The Nature Conservancy, the Minnesota Nongame Wildlife Tax Checkoff, and the Reinvest in Minnesota Program through the Minnesota Department of Natural Resources, Section of Wildlife, Natural Heritage and Nongame Research Program. We also thank the Moorhead State University (MSU), the MSU Foundation, and the Zoological Society of Minnesota for financial assistance.

---

1. Lemen, C. A. and Freemen, P. W. (1985) J Mammal 66, 134-136.

Use of Fly Ash in High-Flexural-Strength Ceramics

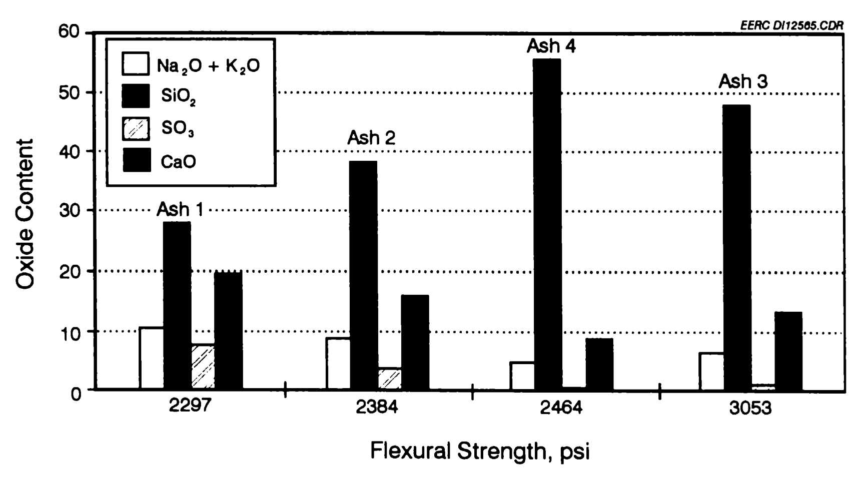
Diane K. Ingvalson and Bruce A. Dockter
UND Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58203

Previous empirical tests at the Energy & Environmental Research Center (EERC) have indicated that coal combustion by-products are a viable starting material for the production of a variety of ceramic products, including brick, tile, and high-flexural-strength ceramics. The EERC has focused on high-temperature properties of coal ashes and has provided valuable insight into ash transformations, fouling, and slagging for the utility industry. It is proposed to utilize the information generated in these past projects to develop material selection criteria and product manufacturing techniques based on scientific and engineering characteristics of the ash.

The objective of this work was to demonstrate the development and production of a ceramic material utilizing coal ash as a key component. Chemical and high-temperature properties of ash were carefully determined with the objective of identifying criteria for materials selection and manufacturing options for ceramic production. A literature search was initiated with a review of past research performed at the EERC. This work included the mix design and laboratory-scale production of ceramic tiles, kilned bricks, and high-flexural strength ceramics. Based on the information reviewed and conversations with industry representatives, it was determined that the ceramic product with the highest commercial potential is likely the high-flexural-strength ceramics with an end use as railroad ties. Previous work in this area showed excellent promise with the only disadvantage being that the fasteners for rails to ties had not been developed for ties made from materials other than wood. Developments in this area in Europe have resulted in successful attachment with a unique fastener which makes the production of railroad ties from alternate materials more viable.

Characterization information on ash used in previous laboratory demonstration of ceramic production was obtained from the Coal Ash Properties Database (CAPD). The CAPD does not currently contain information on high-temperature properties of the ash samples represented. Of particular importance are the fusion temperatures of the ash and the types of crystalline phases that form in the ash during sintering. Where possible, comparisons of information on ash samples with known high-temperature properties and samples from CAPD were made to facilitate the selection of four ash samples for evaluation, mix design, and production. The selected samples were characterized for scientific and engineering parameters, including bulk chemistry, mineralogy, and ash fusion temperatures.

Ceramic bars were produced for all four fly ashes as follows. The materials were blended using a 5-quart mixer. The test mixtures were then extruded into test specimens which were first air-dried overnight and then oven-dried an additional day at 200°F. After cooling to room temperature, the test specimens were arranged in a high-temperature furnace for firing. The total time for the firing process was 11 hours. The furnace was first ramped, for 7 hours, to a peak temperature of 1040°C and held at this peak temperature for 1 hour. This was followed by a 2-hour ramp to 760°C, held at this temperature for 1 hour. Flexural strength was determined on all bars. Results depicting fly ash oxide content vs. flexural strength are shown in the figure. Points of interest include the following: 1) the high-flexural-strength ceramic has a moderate amount of sodium (approx. 6%), lower sulfur (<2%), and moderately high silica (approx. 47%) and calcium; 2) the lowest-flexural-strength ceramic contains the highest sulfur, sodium, and calcium, with the least amount of silica, showed consid- erable flaking on the surface, and was identified as Na_2SO_4 by x-ray diffraction; 3) sodium affiliation with silica, aluminum, and calcium is apparently a critical component to the formation of high-flexural-strength ceramics. The formation of sodium sulfate appears to have a detrimental effect on the strength of the ceramic bars. This reaction ties up the sodium as $NaSO_4$ so it cannot form the more advantageous Na-Al silicates.



THE BIOTIC RESOURCES OF THE GREAT PLAINS: SERVING INFORMATION ON THE INTERNET

Douglas H. Johnson*, Terry L. Shaffer, Shane C. Erstad, Lawrence D. Igl, and Diane L. Larson
National Biological Service, Northern Prairie Science Center, Jamestown, ND 58401

The information explosion that took place in the era of print has burgeoned in the electronic age. The Internet and specifically the World-Wide Web allow nearly instantaneous communication worldwide at comparatively modest costs. The Northern Prairie Science Center has capitalized on these advantages as a means of fulfilling its mission to provide information on the biotic resources of the Great Plains to managers, researchers, academia, and the general public. This paper briefly describes the Center's World-Wide Web site (address: http://www.npsc.nbs.gov/) and some advantages and disadvantages of such methods of information dissemination.

The Web Site

The Web site is a vehicle not only to provide information about the Science Center itself and the work of Center scientists, but also information developed by cooperators. Distributions of animals, bibliographies (some of which are searchable directly over the Internet), computer programs, and connections to complementary Web sites are available.

Advantages

The main advantage of the Internet is wide accessibility; the Center's Web site is reached daily by individuals throughout the world. Web sites can provide more complete information than can printed documents. Large data files can be transmitted with relative ease.

Electronic data bases can be updated far more readily than can printed products. For example, R. A. Royer annually produces an update to his atlas of butterflies in North Dakota [1]. He distributes these updates to individuals he knows are interested, but there is no way to ensure that all owners of the book receive a copy. With his atlas maps now served on the Web, he can update them so that they are available to anyone.

In a similar vein, errors can be rectified easily on a Web site. Mistakes in printed products will remain until a revision is prepared and distributed, or until an easy-to-overlook and easy-to-lose erratum is published. We have corrected errors in printed material we have adapted for our Web site, and can respond quickly to errors detected by users.

Web sites allow timely dissemination of information. Because of long delays in the printing process, many bibliographies, for example, are a year or more out of date when they are published. Electronic publishing minimizes such delays.

Finally, electronic communication affords innovative ways of developing and disseminating information. We are currently developing what might be termed "living bibliographies." These lists of references will made available on the Web site, and users can propose additions or corrections. For example, we will serve a basic list of references dealing with the ecological restoration of savannas. Any user aware of references not included in our list can electronically send those citations to the Web site, where we can add them. With some cooperative effort, this procedure will facilitate the development of a more complete bibliography than could be obtained by individuals working alone. Many such opportunities exist for feedback and cooperation between users and providers.

Disadvantages

The new technology does not come without drawbacks, of course. For one, there is at present no standard method of citing information served on Web sites. Although Web addresses can be cited, the actual resource served can change, making it a "moving target." Advantages listed earlier about the ease of updating information become deficiencies in terms of citing the source.

Electronic publications can evade the rigorous review that printed products, especially scientific journals, often undergo. For electronic journals, protocols for peer review currently are being implemented. Nonetheless, the veracity of much information provided on the Internet will be unproven.

---

1. Royer, R.A. (1988) Butterflies of North Dakota: An Atlas and Guide, Minot State Univ. Sci. Monogr. 1.

THE STATE OF SCIENCE EDUCATION REFORM IN NORTH DAKOTA

Debra Tomanek
Department of Botany/Biology, North Dakota State University Fargo, ND 58105

Science education in K-12 schools and universities has changed little over the years. Advances in science through research have dramatically altered the content of science. However, little has changed in the ways we teach students about science. The majority of science classrooms are still characterized by teacher-centered lessons and prescribed activities that leave little opportunity for questioning and discourse. Over thirty years of science education research has shown us that it is not working. Scientific literacy among the general population is shallow and perceived as irrelevant to daily life. Additionally, the more able K-16 science students excel at memorizing facts, but they lack the deep understanding that we desire.

These conditions have resulted in a call for reform of science education by several professional organizations and learned societies (1, 2, 3, 4, 5). The National Research Council has recently completed their response to the call for reform by publishing the final draft of the *National Science Education Standards*. The *Standards* represent several years of research and synthesis of information on issues relating to student learning and understanding of science, exemplary teaching practices that promote student understanding, effective teacher preparation and professional development programs, and supportive school, university, and state educational systems. The *Standards* represent a road map to help states improve the teaching and learning of science at all levels of the educational enterprise.

Reform projects have been initiated in North Dakota in response to the recommendations from the national level. Yet, we are far behind most other states in our efforts to revitalize science and mathematics teaching and learning. An example of current reform effort is the collaborative work currently being conducted by faculty from various NDUS institutions for the purpose of reforming the preparation of K-12 teachers of science and mathematics. Other groups, such as the ND Alliance for Science and Mathematics, meet regularly to organize and give direction to the use of funds for science and mathematics inservice programs in the state. The *Standards* represent the unifying themes for the work of all reform activity currently conducted in North Dakota and ought to provide a road map for future activity.

----

1. American Association for the Advancement of Science. (1989) Project 2061: Science for All Americans. Washington, D.C.:AAAS.
2. Carnegie Task Force on Teaching as a Profession. (1986) A Nation Prepared: Teachers for the 21st Century. New York:Carnegie Forum on Education and the Economy.
3. National Commission on Excellence in Education. (1983) A Nation at Risk: The Imperative for Educational Reform. Washington, D.C.:U.S. Department of Education.
4. National Research Council. (1996) National Science Education Standards. Washington, D.C.:National Academy Press.
5. Rutherford, F.J. and Ahlgren, A. (1990) Science For All Americans. New York, NY:Oxford University Press.

Friday, 27 April, 1996

9:00 A PROPOSED MODEL for the INTERACTION of F-ACTIN and ALDOLASE
Tim J Keith, **Stephen L Lowe***, Harvey R Knull, Biochemistry & Molecular Biology, UND School of Medicine and Chemistry, Minot State University, Minot

9:20 ACETYLATOR GENOTYPE (*NAT2*)-DEPENDENT FORMATION of ABERRANT CRYPTS in SYRIAN HAMSTERS and RATS ADMINISTERED 3,2'-DIMETHYL-4-AMINOBIPHENYL
Yi Feng*, Adrian J Fretland, Wen Jiang, Rick J Wagner, Mark A Doll, William K Becker, David W Hein, Surgery and Pharmacology & Toxicology, UND School of Medicine, Grand Forks

9:40 DIETARY BORON ALLEVIATES GROWTH CARTILAGE ABNORMALITIES INDUCED by VITAMIN D DEFICIENCY in CHICKS
Kay A Keehr* and Curtiss D Hunt, USDA/ARS Human Nutrition Research Center, Grand Forks

break

10:20 EFFECT of *in vitro* SUPPORT SYSTEMS on the MORPHOLOGICAL CHARACTERISTICS of HUMAN COLON ADENOCARCINOMA and CHORIOCARCINOMA CELLS
Mary Briske-Anderson*, Samuel M Newman, Phillip G Reeves, USDA/ARS Human Nutrition Research Center, Grand Forks

10:40 PREDICTING DAILY ENERGY REQUIREMENTS of WOMEN
W A Siders*, H C Lukaski, D A Krause, L A Mattys, USDA/ARS Human Nutrition Research Center, Grand Forks

11:00 GLUTATHIONE CONTENT and ADRIAMYCIN TOXICITY in HUMAN LUNG CARCINOMA CELLS
Emiko L Hatcher*, Judith M Alexander, Y James Kang, Pharmacology & Toxicology, UND School of Medicine, Grand Forks

11:20 COMFA/QSAR of CAMP BINDING SITES of CAMP DEPENDENT PROTEIN KINASE
Stephen L Lowe*, Wallace Muhonen, John B Shabb, Chemistry, Minot State University and Biochemistry & Molecular Biology, UND School of Medicine, Grand Forks

11:40 DIETARY SUPPLEMENTATION of PHYSIOLOGICAL AMOUNTS of BORON INCREASES PLASMA and URINARY GORON of PERIMENOPAUSAL WOMEN
Forrest H Nielsen*, USDA/ARS Human Nutrition Research Center, Grand Forks

1:30 ABSORPTION and DISTRIBUTION of BORON in RATS FOLLOWING A SINGLE ORAL DOSE of BORON
Yisheng Bai* and Curtiss D Hunt, USDA/ARS Human Nutrition Research Center, Grand Forks

1:50 CLONING and RECOMBINANT EXPRESSION of HUMAN *NAT2* ALLELES *NAT2*17, *18, *5D, *6C, *14C, *14D, and *14E*
David W Hein*, Mark A Doll, Kevin Gray, Adrian J Fretland, Pharmacology & Toxicology, UND School of Medicine, Grand Forks

2:10 IRON DEFICIENCY and SUPPLEMENTATION IMPACT THERMOREGULATION and BROWN ADIPOSE TISSUE (BAT) MITOCHONDRIAL MORPHOLOGY of RATS EXPOSED to COLD

K G Michelsen*, C B Hall, S M Newman, Jr, E A Droke, M E Sleeper, H C Lukaski, USDA/ARS Human Nutrition Research Center, Grand Forks

2:30 DEVELOPMENT of a NEW METHOD to DETERMINE HUMAN *NAT2* ACETYLATOR GENOTYPES

Mark A Doll*, Adrian J Fretland, Anne C Deitz, David W Hein, Pharmacology & Toxicology, UND School of Medicine, Grand Forks

2:50 DIETARY COPPER and MAGNESIUM AFFECTS ACTIVITY, LEARNING, MEMORY, and ANXIETY in RATS

James G Penland*, Karen K Speaker, Patricia L Moulton, USDA/ARS Human Nutrition Research Center, Grand Forks

A PROPOSED MODEL FOR THE INTERACTION OF F-ACTIN AND ALDOLASE

Tim J. Keith[1†], Stephen L. Lowe[2*] and Harvey R. Knull[1]
[1]Dept. of Biochemistry and Molecular Biology, University of North Dakota School of Medicine, Grand Forks, ND 58202
[2]Dept. of Chemistry, Minot State University, Minot, ND 58707
†Current address: Department of Chemistry, School of Math and Science, Chadron State College, Chadron, NE 69337

The cytoskeletal and structural proteins actin and tubulin are ubiquitous in the cytoplasm of eukaryotic cells and are known to bind a number of glycolytic enzymes, including aldolase. That bound proteins are released when ionic strength is increased is consistent with the hypothesis that the binding to both these structural proteins is electrostatic in nature.

In an effort to identify specific residues responsible for binding, one of us (TJK) crosslinked aldolase to actin using EDC (1-ethyl-3-(dimethylaminopropyl)carbodiimide); approximately 10% of the aldolase molecules were crosslinked. Hydrolysis of the crosslinked product with hydroxylamine, which selectively cleaves between asparagine and glycine, produced a 12mer fragment of actin crosslinked to the entire aldolase molecule. Sequencing of the fragment demonstrated that aspartate 3 of actin was linked to aldolase, In addition O'Reilly and Clarke (1) have found that the sequence between residues 32 and 52 of aldolase is involved in the interaction; this sequence includes lysine 41 and arginine 42 which are speculated to be involved in the binding. Using these experimental results regarding specific groups involved in binding, molecular modeling was pursued to look for possible docking sites.

To do molecular modeling, data for the monomers of aldolase (2) and G-actin (3) were used to generate tertiary structures--respectively the tetramer of aldolase and a segment of F-actin--on a Silicon Graphics Indigo work station using the program INSIGHT II (Biosym/Molecular Simulations) from the monomer coordinates downloaded from the protein database.

When comparing the structures on the screen we were struck by the apparent similarity of the repeat distances between protruding monomer units on F-actin with the size of the aldolase tetramer. Originally we had imagined interactions between single subunits of the two proteins but this observation suggested the possibility that the binding may be due to double sets of interactions with side chains of two subunits of each protein involved; there is experimental support for a model involving two subunits of each since binding of aldolase to F-actin is much stronger than is binding to G-actin (Gustafson, C., unpublished results). Measurements both of a number of repeat distances between side chains on F-actin involved in binding glycolytic enzymes and of potentially significant distances between side chains of different subunits in the aldolase tetramer were made.

Some of these potentially significant distances are:

On Aldolase:			
Lys 317 to Lys 317:	69 Å	Lys 41 to Lys 41:	48.5 Å
Lys 317 to Lys 41:	61 Å	Lys 316 to Arg 42:	65 Å
Lys 316 to Lys 316:	74 Å		
On F-actin:			
Asp 3 to Glu 99:	59 Å		

Slides of the structures showing these and other measurements will be shown; one of special interest shows a visual attempt to dock the two molecules which shows distances of only a few angstroms between side chains believed to be involved in binding.

Further work using computer programs for protein docking is planned; this should be followed by further laboratory work for proof of validity of the model.

This work was supported by NSF EPSCoR 9108770 and by a North Dakota EPSCoR ROA grant to SLL.

1. O'Reilly, G. and Clarke, F.M. (1993) Febs. Lett. 321, 69-72
2. Gamblin, S., Davies, G., Grimes, J., Jackson, R., Littlechild, J. and Watson, H. (1991) J. Mol. Bio. 219, 573-576
3. Kabsch, W., Mannherz, H. G., Suck, D., Pai, E. F. and Holmes, K. C. (1990) Nature 347, 37-44

ACETYLATOR GENOTYPE (*NAT2*)-DEPENDENT FORMATION OF ABERRANT CRYPTS IN SYRIAN HAMSTERS AND RATS ADMINISTERED 3,2′-DIMETHYL-4-AMINOBIPHENYL

Yi Feng*, Adrian J. Fretland, Wen Jiang, Rick J. Wagner, Mark A. Doll, William K. Becker, and David W. Hein.
Departments of Surgery and Pharmacology & Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

In the United States, colon cancer is the second leading cause of cancer deaths. It is associated with genetic factors and chemical carcinogen exposures. Aberrant crypt foci (ACF), preneoplastic lesions in chemical colon carcinogenesis, were measured in rapid and slow acetylator (*NAT2*) congenic Syrian hamsters and inbred rats administered 3,2′-dimethyl-4-aminobiphenyl (DMABP). Six to 9 month old female rapid (Bio.82.73/H-*Pat*^{r}) and slow (Bio.82.73/H-*Pat*^{s}) acetylator congenic hamsters received a subcutaneous injection (100 mg/kg) of DMABP at first and second week. Age-matched female rapid (F-344) and slow (WKY) acetylator inbred rats received the same treatment in one group and received 50 mg/kg DMABP twice in the other group. Control animals received vehicle (peanut oil). Ten weeks after the first injection, the animals were sacrificed and each whole cecum, colon, and rectum was stained with 0.2% methylene blue, fixed in 4% paraformaldehyde and examined under a dissecting microscope. No ACF were observed in control animals. However, ACF were identified in cecum and colon in hamsters and in colon and rectum in rats administered DMABP. Distributions of ACF were more concentrated in cecum and proximal colon in hamsters and in distal colon in rats. In hamsters administered DMABP, frequencies of ACF in colon were significantly higher in rapid acetylators than in slow acetylators (Table 1). In rats administered DMABP, frequencies of ACF in colon and rectum were higher in rapid acetylators than in slow acetylators at 100 mg/kg; and frequencies of ACF in descending colon, total colon and total colon + rectum were significantly higher in rapid acetylators than in slow acetylators at 50 mg/kg (Table 2).

Table 1. Distribution of aberrant crypt foci in rapid and slow acetylator congenic hamsters administered DMABP

		Aberrant Crypt Foci				
Acetylator Genotype	N	Cecum	Ascending Colon	Transverse Colon	Descending Colon	Total Colon
Rapid	8	46.5 ± 11.0	2.75 ± 0.77	4.38 ± 1.82	1.50 ± 0.60	8.62 ± 2.37
Slow	9	23.2 ± 9.8 (p=0.1341)	1.78 ± 0.57 (p=0.3212)	0.78 ± 0.40 (p=0.0593)	0.44 ± 0.24 (p=0.108)	3.00 ± 0.91 (p=0.0349)

Table 2. Distribution of aberrant crypt foci in rapid and slow acetylator inbred rats administered DMABP

			Aberrant Crypt Foci					
Dosage (mg/kg)	Acetylator Genotype	N	Ascending Colon	Transverse Colon	Descending Colon	Rectum	Total Colon	Total Colon/Rectum
50	Rapid	7	0.29 ± 0.18	0.43 ± 0.20	2.29 ± 0.57	0.29 ± 0.29	3.00 ± 0.69	3.29 ± 0.92
	Slow	8	-0- (p=0.1197)	0.88 ± 0.35 (p=0.3079)	0.38 ± 0.18 (p=0.0047)	0 ± 0 (p=0.3019)	1.25 ± 0.37 (p=0.0369)	1.25 ± 0.37 (p=0.0496)
100	Rapid	9	0.11 ± 0.11	1.22 ± 0.40	4.11 ± 1.06	1.00 ± 0.55	5.44 ± 1.13	6.44 ± 1.24
	Slow	7	1.00 ± 0.69 (p=0.1707)	1.86 ± 0.51 (p=0.3363)	1.57 ± 0.48 (p=0.0676)	0.29 ± 0.18 (p=0.2917)	4.43 ± 1.17 (p=0.5478)	4.71 ± 1.27 (p=0.3515)

These results suggest that the site of ACF formation differs between hamster and rat and also support the conclusion from human epidemiological studies that rapid acetylator (*NAT2*) genotype is a risk factor for aromatic amine-induced colon cancer. Partially supported by USPHS Grant CA-34627.

DIETARY BORON ALLEVIATES GROWTH CARTILAGE ABNORMALITIES INDUCED BY VITAMIN D DEFICIENCY IN CHICKS

Kay A. Keehr*, and Curtiss D. Hunt
USDA, ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202

Previous research has shown that dietary boron affects several physiological indices in vitamin D (Vit D) deficient chicks including growth cartilage maturation (1). Furthermore, boron, independent of Vit D, had an effect on the morphology of the mineralization zone of the chick growth plate (2). The objective of this experiment was to characterize the interaction between boron and Vit D as it affects bone histology.

Day-old cockerel chicks (20 per group) were fed a ground corn-casein-corn oil basal diet containing 0.08 mg B/kg and adequate in all other vitamins and minerals. Five of the dietary treatments were 125 IU Vit D_3/kg (inadequate) and supplemental boron (as H_3BO_3) to achieve final concentrations of 0.08, 0.27, 0.64, 1.63, or 4.20 mg B/kg, all within a physiological range. The other three dietary treatments were 625 IU Vit D_3/kg (adequate) and supplemental boron to achieve 0.08, 0.64, and 4.20 mg B/kg. Chicks were housed in all plastic environmental chambers and had free access to food and deionized water which was provided fresh each day. The chicks were exposed to 24 hr fluorescent ceiling light with an intensity of (200 lux). At age 28 days, the dissected right proximal tibiae were sectioned with a razor blade in the coronal plane through the center of the medial and lateral tubercles. Sections were fixed with 10% neutral buffered formalin and stained with Alcian blue. The midpoint heights of the articular cartilage (AC), and of the epiphyseal growth plate (GP) and calcified zone (CZ) were obtained by image analysis at low level magnification (~6.5 X). The data were analyzed statistically by linear regression analysis based on the natural log of the dietary boron concentrations.

As indicated in Fig. 1, a range of dietary boron affects growth plate morphology in Vit D-inadequate, but not Vit D-adequate chicks. For example, progressive increases in the amount of dietary boron added to a low-boron diet provided overall reduction in the heights of the abnormally thickened growth plate; ($P<0.001$; $R^2 = 0.16$). Concurrently, the dietary treatments improved height of the calcified zone; ($P<0.03$; $R^2 = 0.07$). In other words, dietary boron ameliorated the defects in cartilage maturation and calcification induced by Vit D deficiency. These finding provide further indirect evidence that dietary boron enhances the metabolic utilization of Vit D. Because dietary boron apparently provides beneficial effects to the vitamin D deficient chick, further research is necessary to establish the range of dietary boron that maximizes growth plate maturation.

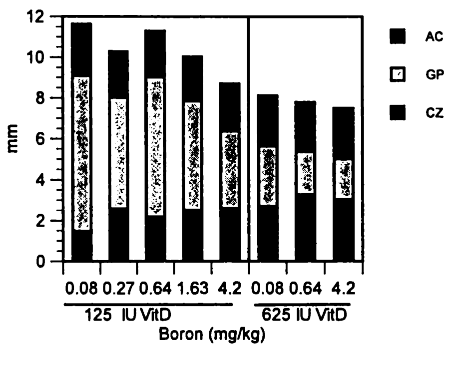


Figure 1.

1. Hunt, Curtiss D., et al. (1994) J. Bone Min. Res. 9, 171-182.
2. Hunt, Curtiss D. (1989) Biol. Trace Ele. Res. 22, 201-220.

THE EFFECT OF *IN VITRO* SUPPORT SYSTEMS ON THE MORPHOLOGICAL CHARACTERISTICS OF HUMAN COLON ADENOCARCINOMA AND CHORIOCARCINOMA CELLS

Mary Briske-Anderson*, Samuel M. Newman, and Philip G. Reeves
USDA, ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202

The culture of cells *in vitro* is gaining recognition by nutritionists as a suitable model for studying the molecular pathways of nutrient absorption. Caco-2 cells, derived from a human adenocarcinoma, express differentiation features characteristic of mature intestinal cells. JAR cells, derived from a choriocarcinoma, resemble cytotrophoblasts of the human placenta. We have chosen these cell lines as experimental models of uptake and transport of trace metals. Adherent cell lines such as these are usually grown on solid supports (polystyrene), but for transport studies a permeable surface is required. This study was done to select a suitable permeable membrane that would support the growth and attachment of these cells.

Porous membranes were made of polyethyleneterephthalate (PET) with pore sizes of 0.45, 1, and 3 µm or polycarbonate, pore size 0.45 µm. The 0.45 µm membranes were available in two porosities, low (1.6×10^6 pores/cm^2) and high (1.0×10^8 pores/cm^2) density. The membranes were coated with 10 µg of rat tail collagen type I per cm^2. Caco-2 cells, seeded at a density of 250,000 cells/membrane or 300,000 cells/T-25 flask were grown in Dulbecco's Modified Eagles Medium supplemented with 4.5 g/l glucose, 1% nonessential amino acids, and 10% fetal calf serum. JAR cells, seeded at a density of 688,000 cells/membrane, were grown in 90% Minimum Essential Media and 10% fetal calf serum. Duplicate cultures were embedded for electron microscopy at growth day 21 for Caco-2 cells and day 3 for JAR cells.

A characteristic feature of transporting epithelia, such as Caco-2 cells, on solid supports is a blister-like hemicyst known as a dome. Dome formation by Caco-2 cells is caused by fluid and electrolyte accumulation between the cell monolayer and the solid surface (1). It has been reported that the number of domes formed in Caco-2 cultures grown on porous surfaces decreases as the pore size or density increases (2). Light micrographs of our Caco-2 cells grown on various porous membranes show that domes do not form. However, another feature that we call multicellular protrusions does form within the monolayer. This feature apparently is not related to the method of seeding, health or passage number of the cells at subculture (3). A comparison of monolayers of Caco-2 cells on membranes of various pore sizes and densities showed that high density 0.45µm PET and 0.45µm polycarbonate membranes had the lowest incidence of multicellular protrusions. The question of whether these multicellular protrusions are a form of dome was evaluated morphologically. We found that the surface of domes typically was one cell thick. However some domes contained thickened areas at their periphery, similar in morphology to the multicellular protrusions on the porous membranes. In our opinion, the multicellular protrusions are an inherent feature of Caco-2 cells and are probably not related to domes. As with domes, the frequency of the protrusions is responsive to the porosity of the support system.

In contrast to Caco-2 cells, the porosity of the support membrane does not affect the morphology of JAR cells. JAR cells consist of a mixed population of cytotrophoblast-like and immature syncytial-like cells. Adherence to the support system is the main concern in evaluating the acceptability of a porous support for JAR cells. All permeable membranes tested supported an adhered cell layer for the required growth period (3 days).

In conclusion, our investigation showed that a high density 0.45 µm pore membrane supports growth of both cell types and decreases the number of multicellular protrusions within a Caco-2 culture. Pore sizes of 1-3 µm allowed migration of cells through the membrane.

1. Ramond, M.J., et al., (1985) Biol. Cell 54, 89-92.
2. Halleux, C. and Schneider, Y.J., (1991) In Vitro Cell. Dev. Biol. 27A, 293-302.
3. Briske-Anderson, M., Finley J., and Newman, S., (submitted for publication).

PREDICTING DAILY ENERGY REQUIREMENTS (ER) OF WOMEN

W.A. Siders*, H.C. Lukaski, D.A. Krause and L.A. Matthys
USDA, ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202

Since the development of the Harris and Benedict (HB) formula (1) for estimating basal energy expenditure (BEE), many methods have been suggested to estimate individual ER. The HB formula, 66+(13.7 x weight)+(5 x height)-(6.8 x age) for women, is usually multiplied by a factor to estimate ER. Recently, the World Health Organization (WHO; 2) has developed equations to predict basal metabolic rate (BMR) for women aged 18-30 yr, 496+(14.7 x weight); 30-60 yr, 829+(8.7 x weight); and > 60 yr, 596+(10.5 x weight). The WHO also recommended multiples of the BMR to make allowances for the intensity of a person's work and discretional activities in the estimation of daily ER. This study compared the predicted ER of women participating in controlled feeding studies with the actual caloric consumption required to maintain body weight.

The 150 subjects were women participating, for at least 120 days, in metabolic feeding studies at the Grand Forks Human Nutrition Research Center from 1985 through 1995. Body weights were maintained for 90-d within 2% of weight at the end of a 30-d control period. At the end of the 30-d weight

Table 1. Physical Characteristics (Mean ± standard deviation)

Age, years	18 - 29 n = 27	30 - 59 n = 52	> 60 n = 17
Weight, kg	64.8 ± 13.7	69.9 ± 11.9	65.4 ± 10.6
Height, cm	165.7 ± 7.8	163.2 ± 7.4	160.6 ± 6.3
BMI, kg/m^2	23.5 ± 3 9	26.2 ± 4.0	25.3 ± 3.7

stabilization period, the HB formula was applied to calculate BEE which was then multiplied by 1.5 to adjust for "medium" activity (3) to predict daily ER. The WHO formulae for three age groups were applied to calculate BMR, which then was multiplied by 1.6 to adjust for "moderate" activity (2) to predict daily ER (Table 2). The predicted ER were subtracted from the actual caloric consumption to maintain body weight and the t-test was used to determine the probability that the difference scores (Δ) were equal to 0. As compared to actual caloric consumption to maintain body weight, the modified HB method predicted significantly lower ER for women aged 30 years and older, whereas the WHO formulae significantly over-predicted ER for women aged 18 to 60 years.

Table 2. Energy needs (Mean ± standard deviation)

Age, years	18 - 30	30 - 60	> 60
Actual	2167 ± 375	2210 ± 230	2002 ± 268
BEE x 1.5	2166 ± 210	2053 ± 203	1858 ± 171
Δ	1 ± 272	152* ± 233	144* ± 242
BMR x 1.6	2319 ± 323	2299 ± 166	2053 ± 178
Δ	-152* ± 258	-94* ± 241	-50 ± 248

* change different than 0, $p<0.01$

Subject age, height and weight were entered into a regression analysis to derive a formula to predict daily ER of women between the ages of 18 and 82 years. The regression equation

ER = 1329 + (15.1 x weight) + (0.012 x height) - (4.50 x age)

has a root MSE = 247 and R^2 = 0.401. While the HB method accurately predicts energy needs for women aged 18 to 30 years, and the WHO formulae are accurate for women over age 60 years, for women between the ages of 30 to 60 years we recommend our formula because it accurately predicts energy needs for women of all ages.

1. Harris, J.A. & Benedict, F.G. (1919) Carnegie Institute of Washington, Publ. No. 279.
2. WHO (World Health Organization). (1985) Technical Report Series 724. Geneva: WHO.
3. Mahalko, J.R. & Johnson, L.K. (1980) Journal of the American Dietetic Association, 77:5, 557-560.

GLUTATHIONE CONTENT AND ADRIAMYCIN TOXICITY IN HUMAN LUNG CARCINOMA CELLS

Emiko L. Hatcher*, Judith M. Alexander and Y. James Kang
Department of Pharmacology and Toxicology, University of North Dakota
School of Medicine, Grand Forks, ND 58202-9037

A major limitation to the clinical efficacy of Adriamycin (ADR), a widely used anticancer agent, is the development of drug resistance. Factors associated with resistance to ADR in tumor cells include enhanced antioxidant capacity, elevated glutathione (GSH) content and overexpression of the membrane glycoprotein P170. Buthionine sulfoxide (BSO), a specific inhibitor of GSH biosynthesis, has been demonstrated to reverse acquired ADR resistance in several tumor cells *in vitro*.[1] The effect of BSO on ADR toxicity in tumor cells with inherent drug resistance is less clear. Non-small cell human lung carcinoma A549 cells contain elevated levels of GSH relative to many tumor cells.[2] The purpose of the present study was to investigate the effect of BSO treatment on cellular GSH levels and on ADR toxicity in A549 cells.

Two subpopulations of A549 cells with a 5-fold difference in ADR sensitivity, termed ADR-sensitive and ADR-resistant, were employed. The basal level of GSH in the ADR-resistant cells is much higher than in the ADR-sensitive cells. Treatment of the cells with 1 mM BSO for 24 hr depleted cellular GSH levels to 10% and 7% of control levels in the sensitive and resistant cells, respectively. This depletion of cellular GSH did not alter the ADR sensitivity in either subpopulation. When the BSO treatment was extended to 36 hr and ADR treatment was applied during the last 12 hr of BSO treatment, the ADR resistance was markedly decreased and the same level of sensitivity was attained in the sensitive and resistant cells. To understand the differential effects of BSO pretreatment alone and BSO pretreatment followed by cotreatment with ADR, GSH content was measured for 12 hr after the 24 hr BSO treatment only, in the presence of ADR, or in the presence of both BSO and ADR (Table 1). The results demonstrate that the resistant cells exhibited a significantly faster rate of GSH recovery in the absence or presence of ADR, although ADR attenuated the recovery in both subpopulations. When the cells were cotreated with BSO and ADR for 12 hr following the 24 hr BSO treatment, cellular GSH remained at the same depleted level in the sensitive and resistant cells. Therefore, these results suggest that cellular GSH must be depleted below a certain threshold level in order to sensitize A549 cells to ADR. In addition, the difference in ADR cytotoxic response in the sensitive and resistant cells may be related to GSH synthesis capacity and the rate of GSH recovery following depletion.

Table 1. Changes in cellular GSH concentrations with various treatments in A549-ADR^S and A549-ADR^R cells.

	A549-ADR^S	A549-ADR^R
Basal Concentration		
Culture time		
12 hr	148.3 ± 0.1	135.7 ± 18.9
24 hr	222.8 ± 19.2	283.5 ± 16.3*
36 hr	191.3 ±12.9	343.4 ± 33.7*
48 hr	163.0 ± 4.7	220.3 ±10.6*
BSO Effects		
Treatment time (culture time)		
24 hr (36 hr)	19.4 ± 1.9	23.4 ± 7.4
36 hr (48 hr)	9.8 ± 0.2	9.5 ± 0.2
Recovery After 24 hr BSO Treatment		
Time post BSO removal (culture time)		
4 hr (40 hr)	14.7 ± 1.9	26.2 ± 8.5*
8 hr (44 hr)	38.3 ± 6.2	73.2 ± 20.4*
12 hr (48 hr)	85.0 ± 6.9	135.4 ± 16.9*
Recovery in the Presence of ADR		
Time post BSO removal (culture time)		
4 hr (40 hr)	16.1 ± 0.4	18.0 ± 4.0
8 hr (44 hr)	24.6 ± 10.6	32.4 ± 15.3
12 hr (48 hr)	77.5 ± 16.1	117.9 ± 7.6*
Depletion in the Presence of ADR and BSO		
Time post 24 hr BSO treatment (culture time)		
4 hr (40 hr)	11.4 ± 1.2	10.9 ± 3.4
8 hr (44 hr)	7.6 ± 3.4	8.1 ± 3.9
12 hr (48 hr)	10.2 ± 0.5	9.4 ± 0.1

1. Dusre, L., Mimnaugh, E.G., Myers, C.E. and Sinha, B.K. (1989) *Cancer Res.* **49**:511-515.
2. Russo, A., DeGraff, W., Friedman, N. and Mitchell, J.B. (1986) *Cancer Res.* **46**:2845-2848.

COMFA/QSAR OF CAMP BINDING SITES OF CAMP DEPENDENT PROTEIN KINASE

Stephen L. Lowe[1]*, Wallace Muhonen[2] and John B. Shabb[2]
[1]Dept. of Chemistry, Minot State University, Minot, ND 58707
[2]Dept. of Biochemistry and Molecular Biology, University of North Dakota School of Medicine, Grand Forks, ND 58202

cAMP-dependent protein kinase is a tetrameric enzyme, R_2C_2, composed of two regulatory (R) and two catalytic (C) subunits. Each regulatory subunit has two cyclic nucleotide-binding domains and, upon binding four molecules of cAMP, the regulatory subunit dimer undergoes a conformational change causing dissociation from the catalytic subunits which then become active. There are two kinds of regulatory subunits (RI and RII). Each regulatory subunit has two cyclic nucleotide-binding domains (A and B sites) which show cooperativity and have very different binding affinities for cAMP analogs. The X-ray crystal structure of the RI type subunit has recently been determined(1). There are also cGMP-dependent protein kinases which are homologous with the cAMP dependent protein kinases but differ in their specificity for the particular cyclic nucleotide and in that the regulatory and catalytic components of cGMP-dependent protein kinase are fused into a single polypeptide.

Dr. Shabb's group is interested in understanding the molecular basis for the differences in selectivities of these different protein kinases. This particular study involves use of extensive analog binding data from the literature to create computer databases for performing quantitative structure-activity relationships (QSAR's) and comparative molecular field analyses (CoMFA's). These QSAR's and CoMFA's were performed on a Silicon Graphics Indigo work station using the programs known as SYBYL 6.2 (Tripos) and INSIGHT II (Biosym/Molecular Simulations).

Producing QSAR's and CoMFA's requires building a database of molecular structures which are entered either atom by atom or using a fragment library. After entry of structures charges are calculated, energy minimizations to find optimal conformations are performed and the molecules are placed in a common alignment. The database is then used to create a molecular spreadsheet containing binding data; CoMFA data of steric and electrostatic field energy around each molecule is generated and, as the final step, a partial least squares analysis is performed to produce the QSAR and CoMFA.

For this study the structures of approximately ninety cAMP analogs were used to create a database and combined with binding data from Ögreid et al. (2) to produce a molecular spreadsheet. These analogs all involve modifications of the purine portion with changes either to the ring itself (as in etheno-cAMP) or modification of groups (as in 6-piperidino-cAMP) or addition of groups (as in 8-azido-cAMP). The torsion angle between the purine ring and the ribosyl moiety was set at the actual angle found for cAMP in the B-site (-51.54°).

The table below gives some results from this initial study. The X-validated r^2 is a measure of the reliability of the model for prediction of binding from the structure. Values of r^2 greater than approximately 0.4 are considered to have some predictive value; values greater than 0.7 are considered good.

Binding Site	**X-validated r^2**	**Optimum # of components**
AI:		
All analogs:	.499	4
without: 8-aza(OH), cXMP	.677	4
BI:		
All analogs:	.297	4
without: 8-aza(OH), cXMP, 8-azido:	.555	5
AII:		
All analogs:	.677	3
without: 8-aza(OH), 8-azido:	.754	3
BII:		
All analogs:	.255	2
without: cXMP, 8-azido 7-deaza-cGMP, cBenzimidazoleMP:	.388	5

These data show that dramatic improvements in r^2 can be made by elimination of just a few analogs and that the "A" sites of both RI and RII are better predicted than are the "B" sites. Explaining the significance of these facts, examination of other possible predictive factors such hydrophobicity and dipole moments, energy minimization within the binding site and focusing on data for particular substituent groups are part of the continuing investigation

The support for this work provided by a North Dakota EPSCoR ROA grant to SLL and by NIH grant R29GM49848 to JBS.

1. Su, Y., Dostmann, W.R.G., Herberg, F.w., Durick, K., Xuong, N-h., Ten Eyck, L., Taylor, S.S., and Varughese, K.I. (1995) Science 269, 807-813
2. Ogreid, D., Ekanger, R., Suva, R., Miller, J., Doskeland, S. O. (1989) Eur. J. Biochem 181, 19-31

DIETARY SUPPLEMENTATION OF PHYSIOLOGICAL AMOUNTS OF BORON INCREASES PLASMA AND URINARY BORON OF PERIMENOPAUSAL WOMEN.

Forrest H. Nielsen*
USDA, ARS, Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202

Studies with postmenopausal women have produced findings indicating that boron can mimic and enhance some effects of estrogen ingestion (1). Estrogen is used to alleviate discomforts associated with menopause including hot flashes and night sweats. Thus, a study was conducted to ascertain whether boron supplementation would alleviate these discomforts in perimenopausal women; the findings showing that boron did not alleviate, and actually exacerbated the discomforts in many of the women supplemented are reported elsewhere (2). This report presents some of the other variables measured including plasma and urinary boron.

The study was a double-blind crossover design with 43 healthy perimenopausal women given sodium borate capsules containing 2.5 mg boron (analyzed) for 60 days followed (19 women) or preceded (24 women) by 90 days when they received a placebo capsule containing lactose powder. The women were encouraged not to markedly change their dietary or exercise habits. Blood was collected weekly via venipuncture after a 12-hour overnight fast. Urine voided in 24 hours was collected three times each week. Plasma and urine boron was determined by using inductively coupled plasma emission spectroscopy. Blood cell counts were determined by a cell counter.

Table 1. Urinary Boron Excretion (mg/day) by Perimenopausal Women Consuming Self-Selected Diets With and Without a 2.5 mg/day Boron Supplement

Treatment	Mean±SD	Median	5th Percentile	95th Percentile	Range of Means**	Range in 3-day pools/subject: Minimums	Maximums
Placebo	1.19 ±0.43	1.15	0.59	2.05	0.34-2.33	0.12-1.62	0.69-4.56
+Boron	3.29*±0.98	3.18	1.98	4.91	1.25-5.83	0.38-3.58	2.72-8.25

*Significantly different than placebo value, P<0.0001. ** Means of nine three-day urine collections from each subject.

Table 2. Plasma Boron Concentrations (μg/ml) in Perimenopausal Women Consuming Self-Selected Diets With and Without a 2.5 mg/day Boron Supplement

Treatment	Mean±SD	Median	5th Percentile	95th Percentile	Range of Means***	Range in blood samples/subject: Minimums	Maximums
Placebo	0.034 ±0.010	0.033	0.023	0.051	0.020-0.067	0.008-0.031	0.023-0.229**
+Boron	0.053*±0.012	0.052	0.033	0.073	0.028-0.075	0.011-0.059	0.039-0.208

*Significantly different than placebo value, P<0.0001. **Probably an outlier; next highest value was 0.127 μg/ml.
*** Means of nine blood samples from each subject.

Table 3. Some Blood Variables Apparently Affected by Boron Supplementation (2.5 mg/day) of Perimenopausal Women

Variable	Placebo-1st	Boron-2nd	Placebo-2nd	Boron-1st	P Values: Treatment	Treatment x Sequence
	24 Subjects		19 Subjects			
WBC,*$10_3/\mu L$	6.16	6.30	6.74	6.92	0.02	0.76
Lymphocytes, %	37.1	35.4	33.2	32.4	0.001	0.15
PMN**,%	56.9	58.8	60.2	61.7	0.0001	0.49

*WBC = white blood cells; **PMN = polymorphonuclear leukocytes.

It is generally accepted that dietary boron is well absorbed and excreted in the urine; this is supported by the findings in Table 1. Subtracting the mean urinary boron excretion value of the placebo treatment from that of the boron-supplement treatment yields 2.1 mg, which is 84% of the 2.5 mg boron supplement. Thus, urinary boron can be considered an indicator of boron intake. The findings during the placebo period indicate that the usual boron intake of perimenopausal women in the eastern North Dakota area ranges between 0.34 and 2.33 mg/day with a median of 1.15 mg/day. With these types of intakes plasma boron concentrations which, as shown in Table 2, range between 0.020 and 0.067 with a median of 0.033 ug/ml, probably should be considered normal. Table 2 also shows that boron supplementation results in a moderate increase in plasma boron concentration. Table 3 suggests that dietary boron can affect the number and distribution of blood cells involved in immune function.

----

1. Nielsen, F.H., Gallagher, S.K., Johnson, L.K. and Nielsen, E.J. (1992). Jr. Trace Elem. Exp. Med. 5:237-246.
2. Penland, J.G. and Nielsen, F.H. (1995). FASEB J. 9:A585.

ABSORPTION AND DISTRIBUTION OF BORON IN RATS FOLLOWING A SINGLE ORAL ADMINISTRATION OF BORON

Yisheng Bai* and Curtiss D. Hunt
USDA, ARS, Human Nutrition Research Center, Grand Forks, ND 58202

There is little information regarding boron (B) absorption and subsequent distribution in animals and humans at normal daily B intakes. This report describes B absorption and distribution in tissues of adult rats previously fed Purina chow [~10 mg B/kg] for their lives. Three of 15 rats (fasted for 2 hr) were killed at 1, 3, 5, 7, and 24 hr following B gavage (as boric acid, 0.15 mg/kg body wt); two rats (fasted for 2 hr) were killed without B gavage at 0 hr to serve as controls. At kill, various tissues were collected, and kept at -24 °C until analyzed for B. All tissues were freeze dried, wet digested, and analyzed for B by using inductively coupled argon plasma emission spectroscopy. Dunnet's t-test was used to determine whether tissue B concentrations increased over time after B gavage (one-tailed t-test).

Boron concentrations (ug/g dry wt, Mean+SEM) in rat tissues at various times following a single boron gavage

hr	Blood[1]	Brain	Heart	Kidney	Liver	Spleen	Testes	Tibiae	Muscle
0	.11±.04	.64±.12	1.0±.18	2.0±.24	.51±.03	3.3±.16	.91±.04	1.3±.05	.50±.03
1	.30±.01*	.77±.06	1.3±.19	2.8±.28	.86±.05*	4.2±.67	1.4±.02*	1.6±.03*	.75±.07*
3	.22±.05	.76±.06	.99±.08	3.0±.11	.83±.03	3.2±.89	1.3±.02*	1.6±.06*	.60±.06
5	.19±.03	.83±.07	.95±.08	3.5±.68	.83±.10	2.6±.33	1.1±.08	1.6±.04*	.50±.05
7	.19±.03	.63±.02	.97±.07	3.5±1.1	.76±.11	2.4±.22	1.2±.15	1.5±.05*	.58±.09
24	.12±.03	.44±.05	.70±.13	3.5±.67	.72±.13	3.5±.67	.97±.06	1.3±.05	.43±.02

* Significantly increased from respective controls ($P < 0.05$). [1] The unit is in ug/mL.

All of the analyzed tissues showed increases in B concentration following B gavage, although the increases were significant only in blood, liver, testes, tibiae, and muscle. Blood and liver B concentrations peaked at 1 hr and slowly declined thereafter. Testes and tibial B concentrations peaked at 1 hr, remained relatively constant for 3 hr and 7 hr respectively, and returned to the base concentrations at ≤ 24 hr. Muscle B concentrations peaked at 1 hr and returned to the base line after 3 hr of B gavage.

The average B intake for young men consuming typical Western diets and B-low water (0.04 ug/mL) is 1.21 mg/d. That average is affected substantially by water B concentrations. For example, the average B intake increases to 2.28 or 6.75 mg/d when the water contains 1 or 5 ug B/mL respectively (1). In the current study, the amount of B (0.15 mg/kg body wt) gavaged is equivalent to 11.25 mg B for a 75 kg adult human, which is 67% higher than B daily intake for humans consuming typical Western diets and water with B concentrations of 5 ug /mL. Our findings demonstrate that B is very quickly absorbed (≤1 hr) when B is provided in the inorganic form, and that there is an unequal distribution of B in the body. The quick absorption of B suggests that some of B are absorbed before it reaches the small intestine. The unequal distribution of B in tissues suggest that B is regulated among tissues by undetermined mechanism(s) in animals.

1. Anderson, D.L., W.C. Cunningham, and T. R. Lindstrom. 1994. Food Compositions and Anal. 7:59-82.

CLONING AND RECOMBINANT EXPRESSION OF HUMAN *NAT2* ALLELES *NAT2*17, *18, *5D, *6C, *6D, *14C, *14D,* and **14E*

David W. Hein*, Mark A. Doll, Kevin Gray, and Adrian J. Fretland
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Human N-acetyltransferases catalyze the N- and O-acetylation of aromatic amine carcinogens and their N-hydroxylated metabolites. Humans as well as other mammalian species exhibit a genetic polymorphism at the *NAT2* gene locus segregating individuals into rapid, intermediate, and slow acetylator phenotypes. The human *NAT2* polymorphism is associated with increased risk to certain cancers caused by aromatic amines derived from food and environmental exposures. To date 23 different human *NAT2* alleles have been identified, 15 of which have been characterized in prokaryotic or eukaryotic expressions systems. N-acetyltransferase activities of the recombinant human NAT2 allozymes vary up to 180-fold. NAT2 4 has high rates of catalysis and is associated with rapid acetylators. In the present study we have cloned and expressed the other eight human *NAT2* alleles in a prokaryotic expression system. The eight new human *NAT2* alleles (**5D, *6C, *6D, *14C, *14D, *14E, *17,* and **18*) have a combination of one to four nucleic acid substitutions in the 870 bp *NAT2* coding region. The *NAT2*17* and *NAT2*18* alleles were constructed by site-directed mutagenesis using polymerase chain reaction (PCR) with two normal external primers and one mutagenic internal primer (Michael, S.F., 1994, *Biotechniques* 16: 410-412). PCR products of each *NAT2* allele were cloned into pUC19 and sequenced. Once identified, *NAT2* cloned alleles were subcloned into the prokaryotic expression system pKK223-3/JM105. Each *NAT2* allozyme expressed relatively equivalent amounts of recombinant NAT2 protein as determined by Western blots with antihuman NAT2 antiserum. As shown in the Table below, NAT2 5D, 6C, 6D, 14C, 14D, 14E, 17, showed reduced capacities to catalyze the N-acetylation of 2-aminofluorene compared to NAT2 4, but had similar affinities (apparent Km) for 2-aminofluorene. NAT2 17 was unable to catalzye 2-aminofluorene N-acetyltransferase activity whereas NAT2 18 catalyzed the reaction at rates nearly equivalent to NAT2 4. Partially supported by USPHS grant CA-34627 and USEPA grant R-821836.

2-Aminofluorene N-Acetyltransferase Michaelis-Menten Kinetic Constants of Recombinant NAT2 Allozymes

NAT2 Allozyme	Nucleic Acid Substitutions	Apparent Vmax (nmol/min/mg)	Apparent Km (μM)
NAT2 4	None	14.9 ± 2.2	52.7 ± 8.0
NAT2 5D	282/341/481/803	0.571 ± 0.132	53.8 ± 7.3
NAT2 6C	282/590/803	2.76 ± 0.52	23.5 ± 2.2
NAT2 6D	590/803	3.00 ± 0.45	25.9 ± 1.6
NAT2 14C	191/282/590	0.258 ± 0.033	20.8 ± 3.8
NAT2 14D	191/341/481/803	0.179 ± 0.006	35.9 ± 22.2
NAT2 14E	191/803	3.17 ± 0.12	34.0 ± 3.6
NAT2 17	434	N.D.	N.D.
NAT2 18	845	11.4 ± 1.1	48.9 ± 6.3

IRON DEFICIENCY and SUPPLEMENTATION IMPACT THERMOREGULATION and BROWN ADIPOSE TISSUE (BAT) MITOCHONDRIAL MORPHOLOGY of RATS EXPOSED to COLD

K G MICHELSEN*, C B HALL, S M NEWMAN, Jr, E A DROKE, M E SLEEPER, H C LUKASKI
USDA/ARS Grand Forks Human Nutrition Research Center, Grand Forks, ND 58202.

The ability of a mammal to maintain its body temperature during cold exposure depends on non-shivering thermogenesis (NST). This is a process that occurs in the mitochondria of BAT and utilizes the uncoupling of oxidative phosphorylation to produce heat. An important regulator of NST is the interaction between thyroid hormone metabolism and the sympathetic nervous system. Iron-deficient (FeD) rats have impaired NST when acutely exposed to cold air and decreased circulating thyroid hormone concentrations. Information about morphological changes in mitochondria of BAT that inhibit the uncoupling of oxidative phosphorylation in response to FeD is lacking. This study examined the effects of dietary Fe restriction and repletion on body temperature, thyroid hormones and BAT mitochondrial morphology during cold exposure.

Weanling, male Sprague-Dawley rats were matched by body weight and fed purified diets adequate in Fe (FeA, 35 ppm Fe; n=24) for 35 d or FeD (7 ppm Fe; n=36) for 30 d. Eighteen of the FeD rats were maintained on the FeD diet for an additional 5 d; 18 other FeD rats were fed the FeA diet for 5 d (FeS). Seven days before the thermoregulation experiment, a thermistor was surgically implanted intraperitoneally to monitor the body temperature (T_B) of each animal. After an overnight fast, half of the rats in each group were maintained at 27°C (RT) and the other half were placed in a chamber at 4°C for 4 h. Upon decapitation cervical blood was collected and prepared for either hematology or plasma thyroxine (T_4) and triiodothyronine (T_3) measurements. Liver and heart were excised for enzyme and mineral analysis. BAT was excised for enzyme, mineral, and electron microscopic analysis. Dissected BAT was fixed in 3% phosphate buffered glutaraldehyde (pH=7.3), post-fixed in 1% OsO_4 then dehydrated in ethanol. The BAT was embedded in EMbed-812. Embedded sections were analyzed on a transmission electron microscope.

Iron-deficient rats were anemic. During cold exposure, FeD, as compared to FeA and FeS, rats did not have a significant increase in plasma T_4 and T_3 concentrations and had a greater rate of decline of T_B (ΔT_B) (Table 1).

Table 1. Hematology and Thyroid Hormone Concentrations (mean ± SD)

	FeA/RT	FeA/4°C	FeD/RT	FeD/4°C	FeS/RT	FeS/4°C
Hct^A, l	0.43±0.02	0.40±0.02	0.23±0.01	0.22±0.02	0.27±0.04	0.28±0.02
Hgb^A, g/L	131±3	138±4	69±5	66±6	81±11	85±6
T_4^B, nmol/L	58±9	86±22	46±14	50±17	48±17	75±14
T_3^B, nmol/L	0.68±0.10	1.34±0.37	0.65±0.21	0.67±0.17	0.70±0.14	1.22±0.22
ΔT_B^B, °C/h	0.003±0.0001	-0.003±0.0001	-0.022±0.002	-0.317±0.007	-0.001±0.0003	-0.019±0.004

ᴬfeA>FeS>FeD, p<0.0001. ᴮsignificant interaction between diet and temperature, p<0.05.

Mitochondria were classified by visual inspection as orthodox (crista folds were non-distended), intermediate (slight increase in crista distention), or condensed (moderate increase in crista distention). Four slides of BAT from each animal were analyzed to obtain the number of each type of mitochondria. The numbers were normalized by determining the percentage of each mitochondrial type for each animal. These percentages were subjected to an arcsin conversion for statistical analysis because of the small number of animals in each group. Regardless of diet, cold induced a shift in mitochondrial morphology to an orthodox state and decreased the percent of mitochondria in a condensed state (Table 2). FeD promoted an intermediate mitochondrial morphology in BAT.

Table 2. Arcsin Transformation of the Percentages of BAT Mitochondrial Types (mean ± SD; ND = not detectable)

	FeA/RT	FeA/4°C	FeD/RT	FeD/4°C	FeS/RT	FeS/4°C
ORTHODOX[A]	0.30±0.31	0.69±0.20	0.42±0.51	0.89±0.33	ND	0.81±0.17
INTERMED.[B]	1.19±0.37	0.88±0.20	0.45±0.44	0.39±0.24	0.92±0.42	0.76±0.17
CONDENSED	0.21±0.18	ND	0.79±0.52	0.38±0.45	0.65±0.42	ND

ᴬ4°C significantly less than RT, p<0.002. ᴮfeD significantly less than FeA, p<0.005.
ᶜ4°C significantly less than RT, p<0.05.

These findings indicate that FeD results in impaired thermoregulatory function and morphological changes in the mitochondria of BAT. Short-term supplementation of FeD rats with Fe restores thyroid hormone status and mitochondrial morphological characteristics that promote NST. These mitochondrial changes indicate a shift towards oxidative phosphorylation for ATP production in FeD which is redirected toward an uncoupling of oxidative phosphorylation in the FeA and FeS animals.

DEVELOPMENT OF A NEW METHOD TO DETERMINE HUMAN *NAT2* ACETYLATOR GENOTYPES

Mark A. Doll*, Adrian J. Fretland, Anne C. Deitz, and David W. Hein
Department of Pharmacology and Toxicology
University of North Dakota School of Medicine, Grand Forks, ND 58202

Humans express two acetyltransferase isozymes (NAT1 and NAT2) which catalyze the *N*-acetylation of arylamines, and the *O*- and *N,O*-acetylation of their oxidized metabolites. Genetic variation at the *NAT2* locus is responsible for the classical *N*-acetylation polymorphism resulting in rapid, intermediate, and slow acetylator phenotypes. Genetic differences in NAT2 phenotype confer corresponding differences in the biotransformation of arylamine and hydrazine drugs as well as environmental and occupational carcinogens, resulting in a genetic predisposition to different cancers. Human epidemiological studies have reported an association between slow acetylator phenotype and the incidence and/or severity of urinary bladder cancer related to arylamine exposures. Conversely, other human epidemiological studies have shown associations between rapid acetylator phenotype and the incidence of colon cancer which may involve heterocyclic arylamine carcinogens present in cooked foods. In addition to the wild-type allele (*NAT2*4*), twenty-two additional mutant *NAT2* alleles have been identified. Each of the mutant *NAT2* alleles possess a characteristic combination of one to four nucleic acid substitutions occurring at positions 191, 282, 341, 434, 481, 590, 803, 845, and 857, of the 870 bp *NAT2* coding region. We have developed an efficient polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) method to distinguish between each of the twenty-three (*NAT2*4, *5A, *5B, *5C, *5D, *5E, *6A, *6B, *6C, *6D, *7A, *7B, *12A, *12B, *12C, *13, *14A, *14B, *14C, *14D, *14E, *17,* and **18*) *NAT2* alleles that have been identified in human populations. The human NAT2 gene is amplified using PCR. PCR products are digested with various restriction enzymes to detect the presence or absence of various nucleotide substitutions (Table 1). The method should facilitate molecular epidemiological investigations of genetic predisposition to cancer from arylamine chemicals. Partially supported by USPHS grant CA-34627.

Table 1. *NAT2* Nucleotide Substitutions and Restriction Site Changes

Position	Nucleotide Substitution	Restriction Site Change
191	G→A	*Msp* I site deleted
282	C→T	*Fok* I site deleted
341	T→C	None
434	A→C	*Msp* I site added
481	C→T	*Kpn* I site deleted
590	G→A	*Taq* I site deleted
803	A→G	*Dde* I site added
845	A→C	*Dra* III site added
857	G→A	*Bam*H I site deleted

DIETARY COPPER AND MAGNESIUM AFFECTS ACTIVITY, LEARNING, MEMORY AND ANXIETY IN RATS

James G. Penland*, Karen K. Speaker and Patricia L. Moulton
USDA, ARS, Grand Forks Human Nutrition Research Center, Grand Forks, North Dakota 58202.

The role of trace elements in neuropsychological function and behavior, particularly in adults, remains largely unknown and unexplored. Copper (Cu) and magnesium (Mg) are two mineral elements of potential relevance to behavior because of their importance in neurotransmitter metabolism (1,2). Further, previous studies have shown a relationship in rats between dietary intakes of both minerals and brain electrophysiology (3,4). Such changes in brain function suggest that behavior, including both cognitive and emotional processes, might be affected. Two controlled studies with mature rats are described below which directly examined the effects of dietary Cu and Mg intakes on several cognitive and emotional behaviors.

In the Cu study, 60 (30 male) Long-Evans rats, aged 85-d, were fed an AIN93G diet containing either 0.5 or 6.0 µg/g Cu (cupric carbonate) for 10 wks. In the Mg study, 100 (50 male) weanling Long-Evans rats were first fed rat chow during a 14-month growth-only period, followed by a 4-wk washout period when they were fed an AIN93G diet. Rats were then divided into two treatment groups and fed an AIN93M diet containing either 50 or 500 µg/g Mg (Mg oxide) for 10 wks. In both studies, drinking water was demineralized. Three behavioral procedures were conducted. Spontaneous locomotor activity was assessed during weeks 5 and 9 with an activity monitor. Sessions lasted 1 hr and included two 5-min periods of auditory stressor (broadband noise at 100 dBA). Measures were number, duration and distance (horizontal only) of horizontal, vertical and stereotypic (repeated circular) movements, and time spent in the center and periphery of the field. Learning and memory were assessed during weeks 6 and 10 with a water maze procedure (5), which involved the rat swimming a complex maze of turns and alleyways to an escape platform at the end of the maze. Three 5-min trials were run each session. Measures of learning were time to complete the maze and number of errors (incorrect turns). To assess memory, rats were tested in the same maze during the second session, but half the rats were required to swim the maze in the opposite direction (i.e., they were started where the escape platform was located during the first session). For rats swimming the maze in the same direction both sessions, memory was reflected in faster times and fewer errors during the second session. For rats swimming the maze in different directions during the two sessions, memory was reflected in interference resulting in slower times and more errors during the second session. To measure emotional reactivity, boli released during trials were also counted. Behavioral anxiety was assessed during weeks 4 and 8 with a standard elevated plus maze, with two closed (walled) and two open arms. Anxiety was reflected by the relative number and duration of visits to the open arms during two 60-second trials. For all procedures, trial data were averaged and sessions analyzed separately with a Diet x Sex analysis of variance that included Direction as a factor in the analysis of water maze performance. All reported results were significant with $p \leq 0.05$.

Activity: Low Cu intake increased the number and duration of stereotypic movements during the second session, whereas low Mg intake resulted in increased number and duration of stereotypic movements during both sessions, more horizontal movements during the first session, and longer duration horizontal movements during the second session. Considering stressor effects, during the first session following noise, females fed low Cu moved longer distances and made more stereotypic movements, while both sexes fed low Cu made more vertical movements. During the second session with noise present, rats fed low Cu spent more total time moving and moved longer distances, made more and longer duration horizontal movements, made more vertical movements, and made more and longer duration stereotypic movements. During the first session with noise present, rats fed low Mg made more horizontal movements and showed increased number and duration of stereotypic movements. During the second session, increased number and duration of stereotypic movements were observed before, during and after presentation of noise. Further, low Mg intake increased number and duration of horizontal movements, movement time and distance per move. Water Maze: Time to complete the maze and number of errors were greater in rats fed low Cu (for females only during the first session) and, during the second session only, in rats fed low Mg and swimming the opposite direction. Low Cu intake also resulted in more boli from females during the first session, while low Mg intake resulted in more boli from both sexes when swimming the opposite direction. Plus Maze: Neither Cu nor Mg intakes were significantly related to any of the measures from the plus maze procedure.

In summary, low dietary intakes of both Cu and Mg were associated with an increase in generalized activity. Low Cu intake also resulted in more stereotypic behavior during presentation of an auditory stressor, whereas low Mg intake resulted in increased stereotypic behavior regardless of the presence of the stressor. Low Cu intake was associated with poorer performance on measures of learning, whereas low Mg intake was associated with poorer performance on measures of memory. Neither Cu nor Mg intakes showed effects on the most direct test of anxiety; however, measures of stressor effects during activity monitoring and memory testing suggest that both minerals may impact emotionality. Sex frequently interacted with Cu intakes on measures of activity and learning and memory. Findings indicate that both copper and magnesium deprivation have functional consequences at the behavioral (and possibly emotional) level, which complement earlier findings of effects of these two minerals on brain physiology. Future studies must further specify their role in behavior and establish minimum intakes required to avoid negative consequences.

---

1. Prohaska, J.R. (1987) Physiol. Rev. 67, 858-901.
2. Chucktow, J.G. (1990) in Metal Ions in Biological Systems, (Sigel, H. and Sigel, A., eds), pp 441-461. Dekker, NY.
3. Penland, J.G., Sawler, B.G. and Klevay, L.M. (1989) J. Trace Elem. Exp. Med. 2, 239-256.
4. Depoortere, H., Francon, A. and Llopis, J. (1993) Neuropsychobiology 27, 237-245.
5. Kant, G.J. (1993) Pharmacol. Biochem. Behav. 44, 287-295.

Special Acknowledgments

Contributors to the North Dakota Science Research Foundation

David L Berryhill
John D Eide
George T Gillies
William Thomas Johnson
Harold A Kantrud
Clark Markell
Kim G Michelsen
Forrest H Nielsen
William Siders
Armand M Souby
Michael B Thompson

Sponsor/Patron

Eric Clausen

On behalf of the members of the Academy, I thank you for your generous sponsorship of our programs and goals. I hope you can take pleasure in association with scientists from the breath of North Dakota and adjoining states. Your names have been entered in this place of honor.

With highest regards and grateful thanks, I remain

Roy Garvey,
Secretary-Treasurer

PROSPECTS and PROBLEMS of DEVELOPMENT in NORTH DAKOTA

A Symposium Organized by: **Mohammad Hemmasi**, Geography, University of North Dakota

Thursday, 25 April, 1996 Valley City, North Dakota

The participants in this symposium, although diverse in thier areas of specialization, are all aware of the developmental issues that are facing the state of North Dakota. The contributors will present the results of their research and demonstate applications of Geographic Information Systems and statistical modeling to current problems of development in the state. A discussion of obstacles to development and possible solutions to them will follow the formal presentations.

2:00 OPENING REMARKS
Mohammad Hemmasi, Geography, University of North Dakota, Grand Forks

2:10 The CHANGING ECONOMIC LANDSCAPE of RURAL NORTH DAKOTA
Lowell Goodman, Geography, University of North Dakota, Grand Forks

2:30 An EMPIRICAL STUDY of UNEMPLOYMENT in NORTH DAKOTA
Fatholla Bagheri, Economics, University of North Dakota, Grand Forks

2:50 CREATING JOBS for a VERNACULAR TOURISM REGION in NORTHEASTERN NORTH DAKOTA
Douglas C Munski, Geography, University of North Dakota, Grand Forks

break

3:30 STRATEGY for RECRUITING UNIVERSITY STUDENTS at a TIME of DECLINING HIGH SCHOOL GRADUATES
Mohammad Hemmasi, Geography, University of North Dakota, Grand Forks

3:50 STATUS of GEOGRAPHIC INFORMATION SYSTEMS in NORTH DAKOTA'S K - 12 INSTITUTIONS
Chandra S Balachandran, Geosciences, North Dakota State University, Fargo

4:10 GEOGRAPHIC INFORMATION SYSTEM in GRAND FORKS
Floyd Hickok, GIS Director, Grand Forks - East Grand Forks

4:30 OPEN DISUCSSION

THE CHANGING ECONOMIC LANDSCAPE OF RURAL NORTH DAKOTA

Lowell Goodman*
Department of Geography, University of North Dakota, Grand Forks, ND 58202

The purpose of this paper is to highlight the economic losses faced by rural main streets in North Dakota. North Dakota is at a juncture where hard decisions are necessary. We're losing population, farms, rural businesses, and our young people. Six counties control 78 percent of all retail activity in the state, leaving 22 percent to be divided by the remaining 47 counties. So far, we have faced these problems by avoiding them.

We persist in calling for more rural development, more family farms, and the saving and rebuilding of rural communities. In reality, none of this is going to take place except in an anomaly here or there. Further, this approach doesn't focus on our main concern, the loss of our young people. Only good jobs with good pay and benefits will do this. The focus of this paper is to realistically look at the economic patterns at the state level and generate an understanding of the difficulties faced by rural communities.. By doing so, we force ourselves to actually see our losses. Then we can work to correct them through different approaches and techniques.

Retail patterns have been changing since the end of World War II. These changes were the result of an abundance of cash and new technology developed during the war.

Prior to the war the U.S., and the rest of the industrialized world, was in the depth of a major depression. As a consequence, residents of a community, both town and country folks, transacted all of their business locally. Further, automobiles and the highway system were marginal at best.

During the war, 1941 through 1945, crops were good, prices were good, and jobs were plentiful, but nowhere could you spend your money. Consumer goods were unavailable and anything that was available was rationed.

Following the war, industry made the transition from war goods to consumer goods. Cash was available from the forced savings, and everyone went on a spending spree. New cars, tractors, farm equipment, and consumer products, sold as fast as they could be produced. The "hometown" was the recipient of these good times and life was good.

By 1950 more roads were being hard surfaced with asphalt and autos were being constructed with new technology instead of 1930s technology. The consequences of this was to be disastrous for rural communities. Now, in one hour, a family could travel 50 to 60 miles rather than 25 to 30 miles. It was becoming easy to save your shopping for Saturday and travel 60 to 80 miles to the city. Shopping became an outing or a mini vacation. It is much more exciting to explore the lights and glitter of the city than the same old main street.

Although the 1950s marked the beginning of major changes, they were also good years for rural communities. Auto dealers and farm implement dealers were everywhere. Most towns of 500 or so had at least two auto dealers and at least two implement dealerships. In small town North Dakota, these dealerships often represented the major employment centers of the town. Add those to the employment on main street and those towns were viable.

By the end of the 1950s the impact of the war was well behind us and we had settled in for the long haul. People were beginning to think about something better. Maybe by selling the farm and getting a job their lifestyle would change for the better. Many of these farmers chose to move into their local "hometown" after selling. Consequently, little changed at first. The basic population remained relatively constant. However, the changing farm population changed the basic demand for farm equipment and we began to see farm implement dealers close their doors. Further, following the war the demand for equipment was so high minor lines and short line dealers did well. As demand settled down, often only the major lines continued. With the farm population and number of farms backing off we began to see the demise of rural communities.

<u>Implement Dealers</u>

Year	Number	Employees	Total
1950	760	8	6080
1960	550	10	5500
1970	397	11	4367
1980	306	13	3978
1990	194	14	2716
1994	170	16	2720
		Loss =	3360

Source: ND Farm Implement Dealers

These combined losses came from rural North Dakota. The cities still have their dealers and they are growing. The major sources of employment were closing their doors. The overall number of people associated with a community was decreasing. It was too easy to travel 75 miles or more to a major shopping center. Local residents were now moving to larger commercial and medical centers to live, work, or retire. All of this impacted rural communities in a negative way. There are numerous reasons for the losses, but the common denominator is the loss of people.

Automobile Dealers

Year	Number	Employees	Total
1950	700	20	14000
1960	602	24	14448
1970	313	28	8764
1980	274	32	8768
1990	158	36	5688
		Loss =	8720

Source: ND Automobile Dealers

As discussed, this loss of trade area population began in the 1950s. Today, this out migration is continuing and those who remain are focusing their economic activity on the major shopping centers. No matter where you live in North Dakota you are no more than one hour and thirty minutes from a major shopping center. In the teens and 20s it was at least two hours from the outer limits of the trade area to the hometown main street. Today the travel time is similar but the distance traveled is much farther. In a time/distance function, the consumer has little trouble making the decision to travel 60 to 80 miles to shop.

FARM LOSSES

	1936	1974	1978	1982	1989	1992
Farm s	84000	42710	40357	36431	35289	31123
Operators	NA	38191	34086	30592	29031	25189

Farm Losses (1974-1992) 11,587
Average Loss = 643 per year
Operator Losses (1974-1992) 13,002
Average Loss = 722 per year

TOTAL LOSS

Loss of rural population 57,935
Plus 2584 operators 10,336
Farm population losses create a loss 3,100 on main street
Total Ag Losses 1974-1992 71,343

Auto and Implement dealership losses 12,080

Add families 48,320

Creates main street losses 2,174

Estimated population loss to rural North Dakota between 1974 and 1992 is 121,865 or about 2300 people per country. For rural main street this is a dramatic loss of customers. This trend is continuing. Small town North Dakota will continue to suffer from out migration and main street in rural communities will continue to collapse if we continue our present policy.

Our policy statewide is to save our rural communities by investing measured (small) amounts of funds everywhere. A welding shop that hires three welders, a restaurant on main street that hires five or six part timers, etc. In this scenario, the state will spend thousands of dollars on projects and they will do nothing for the state or solve our main problem-the loss of our young people and, particularly, the young married families. They are leaving the state because we have not made the investments necessary to create good jobs and retain them.

We need to focus our investments in selected growth points strategically located around the state in order to develop industrial areas large enough to provide an alternative for our young people. Further, where you have strong growth points the smaller communities around them often become stronger because they remain as bedroom cities. Throughout the state a journey of 20 to 40 miles is not uncommon. If a good job is available and the commute is reasonable, many people choose to live in their smaller community for what they feel is the quality of life. Today nearly 63,000 North Dakotans get up every morning and commute to a different county to work. Further about 16,000 North Dakotans travel to a neighboring state to work each day!

We must also recognize that the present economic patterns are the result of years of evolution. There is an old saying, "In the end it's economics," and the present patterns are the result of economic choice. To all of a sudden decide we're going to go back to the good old days is fantasy. We need to build on "what is," not on a memory.

There are many "Economic Developers" around the state that are pushing for funds to help them develop retail activity on main street. Main street is contracting because the number of people is contracting. To develop a new store that ten years ago filed bankruptcy is not going to succeed following ten years of decline. This would truly be a waste of our financial resources and suggests that they have missed the concept that we call economic development.

Smaller farm populations impact rural main street and it becomes a vicious cycle spiraling ever downward. Presently the stated goal for our state is to reach a population of 700,000 by the turn of the century. I'd suggest a better goal is to develop an economic base that will keep more of our young people in the state. We can begin by developing growth points each focusing on a particular region of the state. There are several possibilities already in place and we could develop this idea on regions that are already politically established.

Growth points are the logical step to keep more of our young people. Growth points can support larger growth and development because they have the infrastructure, labor pool, and the ability to finance growth. They also have the cultural and recreational activities that can interest and hold young families.

Format changed for printing.\ RGG

Figure 1.

ONE HOUR AND ONE HOUR THIRTY MINUTE COMMUTE ZONES

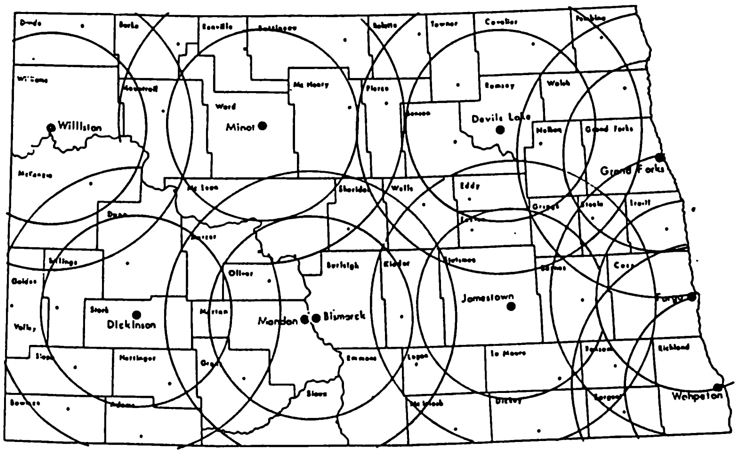
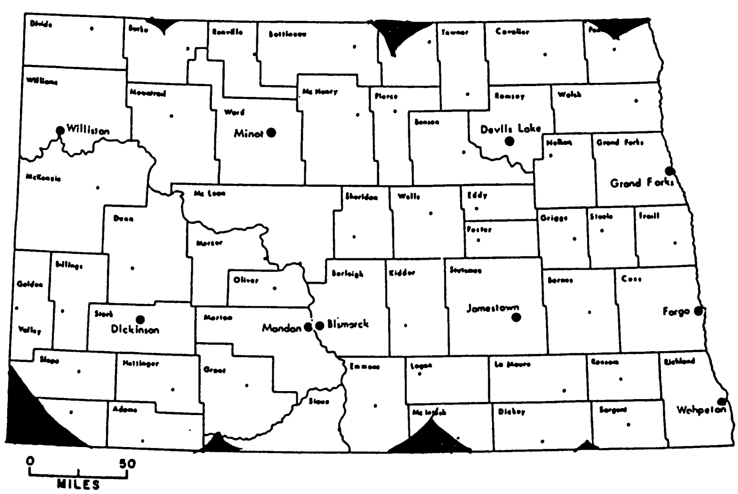


Figure 2.

AREAS MORE THAN ONE HOUR THIRTY MINUTES FROM A GROWTH POINT



AN EMPIRICAL STUDY OF UNEMPLOYMENT IN NORTH DAKOTA

Fatholla M. Bagheri
Department of Economics, University of North Dakota, Grand Forks, ND 58202

INTRODUCTION

In the realm of macroeconomic policy one of the most discussed issues is unemployment. Employment and unemployment statistics are widely used to assess the macroeconomic health of the economy. To both macroeconomists and policy makers, unemployment is the single important measure of labor market performance. It has numerous implications for social and economic growth, and the national well-being. The emphasis in the literature is on the national unemployment rate rather than regional, state and local levels. In reality, however, there are major disparities in unemployment rates across the local labor market areas.

Concern about this issue and the regional impacts of macroeconomic fluctuations have induced a number of empirical studies to explore the cyclical sensitivity of local unemployment rates across states, sub-national regions, and countries.

Two approaches have been pursued by economists to study unemployment differences across local labor market areas. In the first approach, unemployment rate in a given area is specified as a function of some characteristics related to the local economy, the demographic characteristics of the area and some variables representing the aggregate economic conditions. [For example, see Metcalf (7), Behman (1), Browne (3), Fearn (4), Hyclak and Lynch (5), Murphy and Hofler (8), and Murphy (9)]. The second approach examines the changes in the structure of unemployment rates across different regions using measures of dispersions such as standard deviation and the coefficient of variation. [See for example, Iden (6), Sam and Rush (10) and Murphy (9)]. However, none of these authors have addressed the disparity in unemployment rates of local labor market areas at the county level.

The purpose of this study is to identify the spatial dimensions of unemployment disparity over time as measured by the duration and intensity of the unemployment incidence across the 53 counties in the state of North Dakota; and to shed light on the long run structure of unemployment in the counties. Major factors responsible for persistent high unemployment counties vis a vi persistent low and moderate unemployment areas will be discussed. This issue has not been adequately addressed in the previous work despite its great importance for area based-policy purposes.

An understanding of the structure of county unemployment helps state planners to provide specific policies designed to reduce unemployment rates in the target areas. If all counties were faced with a uniform distribution of unemployment, policy makers would not have to be concerned with the sectoral shortages, labor market imbalances, and income inequality when an expansionary policy or a major activity-induced project is implemented in the state. On the other hand, if the geographic distribution of unemployment exhibits high dispersion, the counties with low unemployment may encounter severe inflationary pressures before the level of unemployment in the more depressed counties have been reduced to desirable levels.

ANALYTICAL FRAMEWORK

County unemployment is defined as the difference between the number in the labor force and the number of employed workers. $U = L - E$; therefore, $\Delta U = \Delta L - \Delta E$, where Δ stands for changes. However, changes in the labor force is a function of a host of factors, such as rising real wages, education, natural growth rate of labor force, net migration, job accessibility and other variables affecting households decisions concerning the supply of labor in a given area. Changes in employment is also a function of the variables that affect decisions made by firms concerning the demand for labor. Thus, unemployment equation is the reduced form of a simultaneous system of equations reflecting labor market conditions of a local economy at any point in time. The dynamic features of this market ideally must be sought within the scope of the changes in the underlying variables that are considered to be the building blocks of the local labor market models.

Comprehensive study of this kind of model requires detailed information about certain variables over the sample period. Due to the lack of this information for the North Dakota counties, the ideal study of dynamic features of local area unemployment is beyond the scope of this paper. Nevertheless, we use an alternative approach which may not be a perfect substitute for the ideal procedure outlined above, but fairly comprehensive to shed light on the main objectives of the paper regarding the long-term structure of unemployment across the counties.

DATA AND METHODOLOGY

Unemployment data for the 53 counties of the state were collected for the period 1974-1994.This period covers more than two decades of short run and long run macroeconomic fluctuations that would warrant a fairly reasonable analysis of the long- term structure of the county unemployment rates.

Four methods are used to classify the 53 counties of the state by taking into account the various measures of unemployment rates over the sample period, 1974-1994. In the first approach for each year we ranked the counties based on their respective annual rates of unemployment in a descending order. Then we classified the entire counties into the following five quintiles. The lowest quintile represents persistent high unemployment counties(H), the second quintiles contains counties with relatively high unemployment rates(RH), the third quintile shows counties with moderate unemployment rates(M), the fourth and fifth quintiles comprise Counties with relatively low(RL) and persistently low(L) unemployment rates respectively.

The first section of table 1 shows the spatial distribution of county unemployment rates from which the relative frequency for each quintile could be readily computed. The relative frequencies would indicate an estimated probability that a given county falls in that quintile. The decision rule to classify a county in one of the five areas is the probability in the magnitude of at least 0.5. For example, Adams county falls in the group L with the probability of almost 1 because its relative frequency is 20/21, where 21 is the total number of observations.

In the second approach, we use the relative measure of unemployment by taking the ratio of county to the state unemployment rates for any given year. This concept provides a more meaningful interpretation of the unemployment distribution because it captures the forward and backward linkages that exist between state and county unemployment rates. The state's business cycle and its overall economic conditions may be transmitted to the county and vice versa.

We ranked and classified the 53 counties, based on the relative unemployment rates, in the same procedure and decision criteria as we applied in the first approach. the second part of table 1 indicates the frequency of a county falling in any quintile of the spatial distribution of unemployment.

The third approach involves ranking and classifying the counties, using a specified range of unemployment rates. For the decision criteria we ask what is the probability that a given county falls in the following range of unemployment rates? $0 < u < 3.5$; $3.5 < u < 4.5$; $4.5 < u < 6$; $6 < u < 7$; $u > 7$ There is some degree of arbitrariness in the choice of these numbers. However, two judgmental factors were taken into account. First, North Dakota is mainly a farm state with a larger percentage of agricultural workers than most other states. Therefore, its unemployment rate has consistently been below the national rate. Behman (1) also signifies that unemployment rates for the agricultural-based states are lower than the total national rate. Second, Murphy and Hofler (8) have indicated that, in general, frictional unemployment rates vary widely from region to region. The upper bonds of the first two intervals (3.5 and 4.5), specified above, have been assumed to indicate persistent low or relatively low unemployment areas reflecting the local frictional and structural unemployment rates. Decision rule for the county classification in this approach is the same as before. The bottom part of table 1 shows the number of frequencies corresponding to the classified areas.

In the fourth approach, we use the sample variance, mean and coefficient of variations of the unemployment distribution. these are the statistical measures, widely used in the literature, to assess the extent of inequality in any variable. As the distribution of unemployment becomes more unequal, there is more dispersion in the frequency distribution, implying more variation. One can therefore use the degree of dispersion to measure inequality. A simple measure of inequality is the coefficient of variation which is the standard deviation of the distribution divided by the mean. This measure is unit free, sensitive to changes that occur in the upper range of the distribution, and varies between zero and infinity.

Note that the distribution of unemployment in our study has both space and time dimensions. The spatial variance measures the dispersion of the state unemployment at a given point in time, where as the time variance provides dispersion of the county unemployment rate over the sample period. For the purpose of area classification time variance is appropriate. Therefore, we first calculate the longitudinal mean, variance, and coefficient of variations for every county and second, sort them in the ascending order, and finally break them into quintiles. The counties falling in the lowest quintile, belong to the L area, those falling in the next quintile are classified as RL area, and etc.

DISCUSSION

Table 2 and the North Dakota map show the results of final classifications of the counties based on the common denominator of the four methods used in the study. For many counties the results of various classification methods are overlapping-i.e., the same counties tend to be selected by each method.

Table 2

FINAL COUNTY CLASSIFICATIONS BY UNEMPLOYMENT

HIGH	REL HIGH	MODER	REL LOW	LOW
Bensom	Cavalier	Bottineau	Barnes	Adams
Eddy	Dunn	Burke	Billings	Bowman
Kidder	McLean	Burleigh	Golden V.	Cass
M cHenry	Mercer	Emmons	Grand F.	Dickey
Pembina	Morton	Foster	Logan	Divide
Rollette	Mountrail	Grant	McKenzie	Griggs
Sioux	Oliver	Hettinger	Pierce	LaMoure
	Sheridan	Nelson	Ransom	McIntosh
	Slope	Ramsey	Renville	Steele
	Stark	Richland	Sargent	Towner
	Wells	Walsh	Stutsman	
		Ward	Traill	
		Williams		

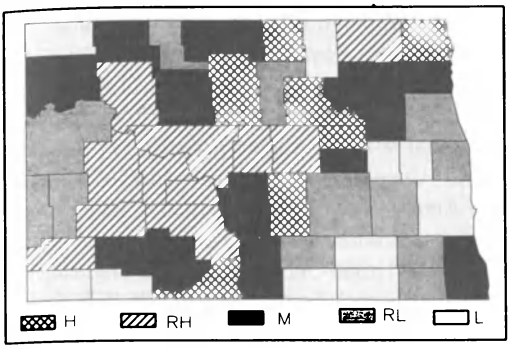


Figure 1. County Unemployment in North Dakota, 1974-1994

On the map, one may observe a cluster of L&RL counties starting from Grand Forks and extending to the southeast. This area covers the Red River Valley farm lands, rich in soil and high in yields, with farming as the major industry. Cass county, with the Fargo / Moorehead communities, appear to be economically performing exceptionally well. Many of the shopping habits of people in the region have shifted to travelling to Fargo for major purchases.

Several other counties in this group are located on west, each of which has its own characteristics. For example, Billings and McKenzie counties have low population and enclose the Theodore Roosevelt National Park. The major activities in the area are tourism and ranching. Some counties like Divide, Adams, and McIntosh have low population and strictly farm and ranching industry. People tend to outmigrate from these counties when jobs are not available. Therefore with the low population, unemployment remains low.

There appear to be two clusters of counties in H and RH groups together, reflecting persistent high and relatively high unemployment areas. One cluster is in the mid central and the other is in south west. They are characterized by the following area specific factors. Coal industry is the major economic activity of the area, especially to the north of Burleigh Corporation in Burleigh county. The trend of employment in this industry has been declining. Coal mine workers often face structural unemployment, due to the lack of alternative desired skill. These workers typically do not migrate to other places for jobs unless they are retrained for the desirable skills. Therefore outmigration does not alleviate the unemployment problem.

The next character specific to high and relativly high unemployment area is the reservation. Unemployment rate is persistently the highest for the counties with the native American reservations. North Dakota ranks fifth in the north central region of the country in terms of native American population There are four major reservations in North Dakota. The Standing Rock reservation located entirely in the Sioux county to the south of Bismarck. The Turtle Mountain reservation which is the smallest one in Rolette county. The Fort Totten reservation spreading over Benson, Eddy and Ramsey in the east central part of the state. The Fort Berthold reservation which is the largest one in North Dakota and covers Dunn, McLean, McKenzie, Mercer, and Mountrail in the western part of the state along the Missouri River.

Among all counties with reservations, McKenzie and Ramsey are the only exceptions as to fall in relatively low and moderate unemployment levels respectively. The exception is due to the fact that the first couny is part of an oil producing region and the second one is strong in tourism. The Sioux county is exclusively a native American reservation which persistently has the state's highest rate of unemployment with an average rate 12.1% over the sample period. Rolette which contains the Turtle Mountain reservation, has the next highest average rate of unemployment at 10.1% over the period of the study.

Clearly this implies that these counties consistently share greater burden of the geographic incidence of unemployment. Generally speaking, the counties classified under H group show a long and persistent unemployment duration. For example, Sioux county falls in this classification 20 times out of 21 possible outcomes. Similar pattern could be observed for Benson, Eddy, Rolette, Pembina, Kidder and McHenry. Among the counties under RH area we do not observe significant changes in the pattern of unemployment except for few short spells of deviations in the general trend of the county unemployment. The general pattern of unemployment distribution supports the hypothesis that the two groups of counties, H and RH, do not converge to the state's unemployment rate. This finding is in contrast to the conclusion reached by others in the literature that a large part of interstates unemployment differences is eliminated over time. It implies that unemployment in the counties is of more structural than cyclical or frictional. More importantly, long-lived spells of geographic unemployment may lead to a labor force whose skill and demographic mix are weighted more heavily toward groups that have high unemployment rates. This is due to the obsolescence of workers' slill and outmigration of the young workers. In many cases Most people think that it is more faire to spread unemployment around evenly than to concentrate it among a few counties or a few people.

The policy implication of our results must be of great concern to the state planners because most workers in a local labor market,generally with limited employment opportunity, can survive a short period of unemployment with little difficulty. Part of the lost earnings will be replaced by unemployment insurance benefits. Living standards can be maintained by consuming from savings and borrowing. But if longer unemployment persists, the consequences would be more serious. Exhaustion of unemployment benefits, depletion of savings, credit drain, deterioration of workers' skill, outmigration, loss of hope and personal dignity and many other social costs are but a few prices that the county community has to pay for the long-lived concentration of unemployment. Long spells of geographic unemployment may also Many efforts have been made in the past and currently is being made to expand economic opportunity in these areas. Yet, many more development plans need to be implemented to increase employment opportunity in these counties. The focus should be on the policy instruments that would aim the specific unemployment target areas as well as the structural issues of the local labor markets.

REFERENCES

1. Behman, S. "Interstate Differentials in Wages and Unemployment," Industrial Relations, May 1978, 17, 168-188.
2. Brechling, F. "Wage Inflation and the Structure of Regional Unemployment," Journal of Money, Credit, and Banking, February 1973,5, 355-384.
3. Browne, L. "Regional Unemployment Rates-Why Are They so Different?" New England Economic Review, July/August 1978, 5-26.
4. Fearn, R. "Cyclical, Seasonal, and Structural Factors in Area Unemployment Rates," Industrial and Labor Relations Review, April 1975,28, 424-431.
5. Hyclak, T. and Gerald L. "an Emperical Anaylsis of State Unemployment Rates in the 1970's," Journal of Regional Science, August 1980,20, 377-386.
6. Iden, G. "Unemployment Classification of Major Labor Areas, 1960-65," The Journal of Human Resources, Summer 1967,2, 375-391.
7. Metcalf, D. "Urban Unemployment in England," The Economic Journal, September 1975,85, 578-589.
8. Murphy, K. and Hofler, R. "Determinants of Geographic Unemployment Rates: A Selectively Pooled-Simultaneous Model," Review of Economic Statistics, May 1984,66, 216-223.
9. Murphy, K. "Geographic Differences in U.S. Unem ployment Rates: A variance Decomposition Ap proach," Economic Inquiry, January 1985, 23, 135-158.
10. Sum, A. and Rush, T. "The Geographic Structure of Unemployment Rates," Monthly Labor Review, 1975, 98, 3-9.

Format changes for printing.\RGG

Table 1
County Classification by Quantiles and the Related Frequencies of Unemployment Distribution

County Classifications by **Absolute** Unemployment rates

Frequency	Class	Adams	Barns	Benson	Billings	Bottineau	Bowman	Burke	Burleigh	Cass	Cavalier	Dickey	Divide	Dunn	Eddy	Emmons	Foster	Golden Valley	Grand Forks	Grant	Griggs	Hettinger	Kidder	LaMoure	McIntosh	McKenzie
Low	1-9	0	0	19	1	0	0	0	0	0	1	0	0	9	19	5	0	0	0	0	0	0	16	0	0	0
Rel. Low	10-20	0	0	2	3	10	0	5	5	0	13	0	0	5	2	7	1	1	3	5	1	3	5	0	2	3
Moderate	21-31	0	6	0	4	9	4	8	10	1	6	0	1	2	0	9	11	7	4	10	0	11	0	2	1	5
Rel. High	32-42	1	12	0	5	2	8	5	6	6	1	6	3	5	0	0	8	4	7	6	12	6	0	10	4	5
High	43-53	20	3	0	8	0	9	3	0	14	0	15	17	0	0	0	1	9	7	0	8	1	0	9	14	8

County Classifications by **Relative** Unemployment

Frequency	Class	Adams	Barnes	Benson	Billings	Bottineau	Bowman	Burke	Burleigh	Cass	Cavalier	Dickey	Divide	Dunn	Eddy	Emmons	Foster	Golden Valley	Grand Forks	Grant	Griggs	Hettinger	Kidder	LaMoure	McIntosh	Mckenzie
High	1-9	0	0	18	0	0	0	0	0	0	0	0	0	8	18	3	0	0	0	0	0	0	12	0	0	0
Rel. High	10-20	0	0	2	2	6	0	3	4	0	12	0	0	6	3	8	1	1	2	4	1	2	9	0	2	2
Moderate	21-31	0	6	1	5	13	3	11	9	1	8	0	0	1	0	10	9	7	4	10	0	11	0	2	1	4
Rel. Low	32-42	1	12	0	4	2	7	4	8	5	1	4	3	6	0	0	10	4	8	7	9	5	0	9	4	7
Low	43-53	20	3	0	10	0	11	3	0	15	0	17	18	0	0	0	1	9	7	0	11	3	0	10	14	8

County Classifications by **Specified Range** of Unemployment Ratets

Frequency	Class	Adams	Barnes	Benson	Billings	Bottineau	Bowman	Burke	Burleigh	Cass	Cavalier	Dickey	Divide	Dunn	Eddy	Emmons	Foster	Golden Valley	Grand Forks	Grant	Griggs	Hettinger	Kidder	LaMoure	McIntosh	Mckenzie
Low	0-3.5	18	6	0	11	4	13	6	2	15	1	15	16	2	0	0	2	11	7	3	11	3	0	14	14	10
Rel. Low	3.5-4.5	3	8	0	6	5	3	5	10	4	5	6	4	6	0	6	12	3	10	7	7	11	1	5	7	4
Moderate	4.5-6	0	6	4	3	9	4	6	4	2	11	0	1	2	2	5	6	6	4	11	3	6	3	2	0	4
Rel. High	6-7	0	1	2	1	1	1	3	5	0	4	0	0	4	4	6	1	1	0	0	0	1	4	0	0	2
High	7-up	0	0	15	0	2	0	1	0	0	0	0	0	7	15	4	0	0	0	0	0	0	13	0	0	1

Table 1
County Classification by Quantiles and the Related Frequencies of Unemployment Distribution

County Classifications by **Absolute** Unemployment rates

Frequency	Class	McLean	Mercer	Morton	Mountrail	Nelson	Oliver	Pembina	Pierce	Ramsey	Ransom	Renville	Richland	Rolette	Sargent	Sheridan	Sioux	Slope	Stark	Steele	Stutsman	Towner	Traill	Wells	Williams
Low	1-9	8	7	4	8	0	1	13	0	0	1	0	0	21	1	2	20	8	3	0	0	0	0	3	3
Rel. Low	10-20	12	7	16	12	7	11	8	0	0	0	2	5	0	4	10	1	5	9	0	2	0	2	8	5
Moderate	21-31	1	4	1	0	11	6	0	0	14	3	5	8	0	2	4	0	3	5	2	8	0	7	9	5
Rel. High	32-42	0	1	0	1	3	2	0	18	6	9	6	8	0	7	4	0	3	4	4	11	3	4	1	4
High	43-53	0	2	0	0	0	1	0	3	1	8	8	0	0	7	1	0	2	0	15	0	18	8	0	4

County Classifications by **Relative** Unemployment

Frequency	Class	Mclean	Mercer	Morton	Mountrail	Nelson	Oliver	Pembina	Pierce	Ramsey	Ransom	Renville	Richland	Rolette	Sargent	Sheridan	Sioux	Slope	Stark	Steele	Stutsman	Towner	Traill	Wells	Williams
High	1-9	5	6	2	4	0	0	8	0	0	1	0	0	21	1	1	16	4	3	0	0	0	0	0	1
Rel. High	10-20	16	8	17	15	6	11	13	0	0	0	2	5	0	4	10	5	9	7	0	1	0	1	11	7
Moderate	21-31	0	4	2	1	11	7	0	0	12	2	4	8	0	1	5	0	3	7	1	7	0	8	9	5
Rel. Low	32-42	0	1	0	1	4	2	0	15	8	7	5	7	0	6	4	0	3	4	5	13	3	4	1	3
Low	43-53	0	2	0	0	0	1	0	6	1	11	10	1	0	9	1	0	2	0	15	0	18	8	0	5

County Classifications by **Specified Range** of Unemployment Rates

Frequency	Class	Mclean	Mercer	Morton	Mountrail	Nelson	Oliver	Pembina	Pierce	Ramsey	Ransom	Renville	Richland	Rolette	Sargent	Sheridan	Sioux	Slope	Stark	Steele	Stutsman	Towner	Traill	Wells	Williams
Low	0-3.5	0	2	0	0	1	3	0	9	5	10	12	3	0	11	2	0	4	4	14	6	18	3	3	7
Rel. Low	3.5-4.5	2	5	1	5	7	6	2	9	6	7	3	10	0	3	6	0	3	4	5	7	3	16	1	4
Moderate	4.5-6	7	4	12	4	8	6	3	3	9	4	3	5	0	3	8	3	3	6	2	8	0	2	7	4
Rel. High	6-7	7	2	5	2	3	3	4	0	1	0	2	3	0	3	4	2	4	3	0	0	0	0	7	3
High	7-up	5	8	3	10	2	3	12	0	0	0	1	0	21	1	1	16	7	4	0	0	0	0	3	3

Creating Jobs for a Vernacular Tourism Region in Northeastern North Dakota

Dr. Douglas C. Munski
Department of Geography, University of North Dakota
Grand Forks, ND 58202

Introduction

Tourism is not the panacea to the economic woes of a region, but people in economically-depressed rural areas frequently attempt to use it as a means to revive the specific region (Gunn, 1994). As pointed out by Joslin (1992), such efforts have been in progress since the late 1980s in the extreme northeastern North Dakota counties of Cavalier and Pembina (Figure 1). This area now is being promoted as the Rendezvous Region. However, based upon a series of field investigations undertaken between 1992 and 1995, it appears that tourism still is not at the level that is necessary to become the economic generator that persists as a goal of numerous citizens in these two counties. This paper is a review of the circumstances of the Rendezvous Region as a vernacular tourism region and contains preliminary recommendations for how increased attention to applied historical geography, a form of historic preservation planning, can increase the attraction of the two counties as a tourist destination.

Background to the Rendezvous Region

The vernacular tourism area being marketed under the name, "Rendezvous Region," is one of the more historic as well as geographically significant parts of the state of North Dakota. Physiographically, the area consists of land in the Red River Valley of the North, i.e., former Glacial Lake Agassiz, on its eastern margin to land in the Drift Prairie, i.e., the Glaciated Plains or Prairie Pothole Country, terrain on its western margin (Bluemle, 1991). Dividing the two geomorphic sub-regions is the Pembina, or as it is better known in regional geography, Manitoba Escarpment (Scott, 1995). In the northern margin of the area is the Pembina River Valley with the Pembina Gorge, one of the most scenic and historically important waterways in the overall drainage system of this part of the greater Hudson Bay basin.

Because of the combination of a Dfb (continental, short summer) climate, aspen-parkland vegetation, and tall grass prairie vegetation, this part of what would become extreme northeastern North Dakota had substantial fauna that could be harvested by the aboriginal people as sources of food, fur, and bone-based implements. Species of importance were the bison (meat and hides) and fur-bearers such as the beaver, the muskrat, the fox, and the rabbit. The Pembina Gorge was and continues to be the only major place in which moose are to be found in this area.

Today's Rendezvous Region was the territory that was dominated by the Plains Ojibwa, often known as the Chippewa, by the early 1700s (Schneider, 1990). However, closeby were the Assiniboine to west and the Dakota to the south with conditions being such that the Ojibwa were allied with the Assiniboine against the Dakota.

While the harvesting of fur-bearers took place prior to the arrival of Europeans with the native peoples having significant intracontinental trade connections (Ray, 1983), the future counties of Pembina and Cavalier started to become heavily exploited for furs only after the arrival of French voyageurs from the east via the Great Lakes-Grand Portage-Winnipeg River system (Gilman, Gilman, and Stultz, 1979). Later, the English with their Scottish and Irish companions came from the north as part of the inland expansion of the Hudson Bay Company.

It is this period of the fur trade which is the basis for the use of the word, "Rendezvous," as the "hook" in the marketing of the area for tourism. It has, of course, not only the meaning drawn from the historical connection of Euro-American fur traders and Native Peoples meeting together for trading, i.e., a rendezvous, but also is being used locally to connate the "romantic" aspects of this contemporary tourist destination.

The role that the Pembina River played in the late eighteenth century and early nineteenth century fur trade was significant. In 1797 the North West Company's Charles Jean Baptiste Chaboillez established a trading post for the North West Company at the confluence of the Red River and the Pembina. By 1801 that facility was supervised by Alexander Henry the Younger who modified the Quebecois charette (a horse cart) into what would be the famous Red River ox cart (Gilman, Gilman and Stultz, 1979). This would prove to be the most significant and heavily used innovation in reducing the geographic friction of distance between the Red River Settlements (today's Winnipeg, Manitoba) and Fort Snelling (today's St. Paul, Minnesota) even after the introduction of the steamboat onto the Red River in 1859. The Red River ox cart traffic increased quite slowly between 1801 and 1849, a reflection of the various geo-political circumstances of that period.

After the North West Company trading post was firmly established, the Hudson Bay Company attempted to make a presence in the area with Fort Daer (within what is today's city limits of Pembina). This facility never was as successful as that of the North West Company in large measure because the Selkirkers (Scottish emigres) who inhabited it on a seasonal basis from 1812-1814 were not as effective as bison hunters as were the Metis.

Today's Rendezvous Region became a focal area for the Metis, the offspring of Europeans and the aboriginal population. Metis hunters of the North West Company made it possible for the fur trade to function effectively because of their twice-yearly bison hunts which were the source for the basic foodstuff utilized by the voyageurs and factors (fur trade post managers): pemmican. Competition over hunting the regional bison herds became quite fierce as well as intensive and was a contributing factor to the Pemmican War of 1816-1821 between the North West Company and the Hudson Bay Company.

Meanwhile, that part of British North America known as Assiniboia was partitioned such that the territory south of the 49th Parallel (which included the area that would become the Rendezvous Region) was transferred to the United States with the remaining land still in the possession of the United Kingdom. This change in the local political geography officially introduced the American fur traders into the area from the south. This in turn stimulated the Hudson Bay Company to encourage the relocation of the Metis from Pembina to White Horse Plains (Jackson, 1970; Gilman, Gilman and Stultz, 1979).

The American influence increased slowly at first, but after 1849, the level of Red River ox cart traffic became quite substantial moving through Pembina. The role of Anglo-Americans such as Norman Kittson must be noted, but the Metis, such as Antoine Gingras, cannot be discounted. The State Historical Society of North Dakota maintains a site just north of Walhalla that is the preserved and reconstructed Gingras Trading Post and Home. This is one of the most significant resources for tourism in the Rendezvous Region as exemplified by the State Historical Society of North Dakota's summer interpretative programs there of "History Alive" and "Gingras Ox Cart Day."

The Rendezvous Region's role in the fur trade's pemmican production gradually diminished with the shift of fur harvesting increasingly to the northwest during the 1830s through 1860s. The Metis population of this part of what was by then Minnesota Territory slowly moved in that direction across the 49th Parallel, too. Yet, there were Metis leaders such as Joseph (Jolly Joe) Rolette who had prominent roles in the Minnesota Territorial Legislature (Tweten and Jelliff, 1976). Even the influence of "Jolly Joe" could not stop the gradual transformation of the fur trade and the rise of other forms of transportation between the Red River Settlements and the expanding commercial center of Minneapolis, Minnesota.

Metis carters slowly were replaced with the arrival of the steamboat on the Red River in 1859, but it was not until the introduction of the steam railroad that the ox cart traffic was reduced to the point of oblivion. For example, during the low water period of 1862, Metis ox carts resumed temporary dominance of the ever-growing traffic coming from the south (Gilman, Gilman, and Stultz, 1979). Increasingly, the northbound traffic was immigrants who were entering the Red River Valley of the North. Beginning in the early 1870s, these Old Stock Americans and Europeans started to make the area of what is now the Rendezvous Region a commercial agricultural zone.

The heritage of the pioneer agriculturalists is a valued theme in the marketing of the Rendezvous Region today. Perhaps this is a reflection of local pride in how Pembina County was once the largest county in Dakota Territory and played a major role in the North Dakota statehood movement of 1889. Maybe there is a longing for what is called romantically, albeit incorrectly, the "Golden Age of Farming," in extreme northeastern North Dakota (Drache, 1970). As pointed out by Jensen (1994), Pembina County had its peak population identified in the Census of 1910 with a steady decline to the present. In Cavalier County the peak population was reached in the Census of 1940, but even this county is now smaller in numbers of residents--a reflection of local rural outmigration since 1940.

Increased mechanization of agriculture in the mid-twentieth century, agrarian dislocation with the impact of the Great Depression of 1929-1939, and the growing attraction of nearby urban centers such as Grand Forks and Fargo as well as more distant locations, e.g., Minneapolis-St. Paul, underlie the transformation of extreme northeastern North Dakota from leading counties in population and economic growth to what might be categorized as an economically stagnant, if not, declining part of North Dakota (Drache, 1970; Stradley, 1981 and 1994).

Early Tourism as an Economic Engine

By the late 1960s, it was evident that the area which now is being marketed as the Rendezvous Region needed an economic boost. Efforts were made to introduce new crops such as sunflower (Narloch, 1979) to increase agricultural revenues, and communities such as Cavalier and Langdon benefitted economically from the establishment of the Cavalier Air Force Station. Yet, diversification of the area's economic geography also included the use of tourism.

Part of the initial tourism development for the area was the result of combining flood control with camping and fishing oriented recreation. The construction of Lake Renwick on the Tongue River, a key tributary of the Pembina River, is a striking example as it stimulated increased utilization of Icelandic State Park, the area's premiere state-controlled recreational area. The State Historical Society of North Dakota did have a museum at Pembina, but repeated flooding of the site, especially the disasterous 1979 flood, forced the state agency to close that small structure. It now is being reopened on the northwest edge of Pembina, and this will relocation will be examined later in this paper. On the other hand, the State Historical Society of North Dakota expanded its facilities at Icelandic State Park and at the Gingras Trade Post.

Private efforts to promote tourism came in the form of Frostfire Mountain, probably the best known of North Dakota's few downhill skiing facilities. Located in the southern part of the Pembina Gorge, Frostfire Mountain's management sponsors a dinner theatre during the summer months. In addition to Frostfire Mountain, the Rendezvous Region has a quite surprisingly strong affinity for golf as reflected in the golf courses (nine and eighteen hole) sprinkled throughout the two counties. Acrimonious competition for the limited tourism market characterized not only the rivalry between these golf courses, but it was reflected in "trade wars" among the four principal settlements of the two counties: Cavalier, Langdon, Pembina, and Walhalla. By the mid-1980s, "truce and peace" were declared because it was counterproductive for the various interest groups to continue to work against each other when cooperation could be mutually advantageous throughout the two counties (Joslin, 1992).

Creating the Rendezvous Region Concept

In the late 1980s there were representatives of the local chambers of commerce, economic development offices, retail establishments, government offices, historical societies, and bodies of recreationalists, e.g., snowmobilers, who began to pool their resources so to be able to retain a consultant from California for a tourism assessment in 1989 (Joslin, 1992). Between 1989 and 1992, the concept of marketing the two counties under the vernacular region name of the "Rendezvous Region" was developed. This tourism promotional name slowly became accepted between 1992 and 1995, but relations between the consulting agency and the representatives of the organizations affiliating as a marketing board for the Rendezvous Region soured sometime during 1993-1994 (Hartje, 1994).

Starting Up the Tourism Machine

Meanwhile, the various groups in this marketing board continued to act in more independent ways than one might have expected, but several cooperative accomplishments were brought to fruition. First, starting in the 1993 summer tourism season, the Rendezvous Region logo became prominently displayed on the major tourism brochures from the marketing board. By 1994 a billboard with the logo was placed along Interstate 29 at a strategic spot near Drayton, North Dakota, to catch the attention of tourists; it continues to be used as a stationary form of advertising. In the summer of 1995 the first major annual cooperative event of the marketing board was undertaken with delightfully successful results for the organizers of the Rendezvous Region Days.

This event was centered upon the Icelandic State Park area and included a variety of events, most notably that of a large encampment of afficiandos of reliving the lifestyle of black powder shooters.

Yet, not all has gone well with the early phase of this tourism effort for the Rendezvous Region. Because empirical evidence from proprietary sources still is not ready for release to public researchers, anecdotal evidence is used to draw this conclusion. That observation is based upon more than six research trips directly into the Rendezvous Region and over twenty field trips along its eastern margin from May of 1993 through January of 1996. There appear to be four major negative restraints upon the area's tourism as of the winter tourism season of 1995-1996.

First, while the name Rendezvous Region is becoming widely utilized in the two county area, it does not seem to garner much name recognition among the tourists that are considered the prime market by the marketing board: Winnipeg and the Twin Cities of Minnesota. Insufficient advertising has been done to lure the Canadians off Interstate 29 on their way to shop and play in Grand Forks and Fargo, and the folks from the Minneapolis-St. Paul metropolitan area have numerous intervening opportunities for tourism before reaching extreme northeastern North Dakota. To be blunt, there is poor, if any, name recognition beyond the two counties. Having merely a single billboard on an interstate highway is only a start on correcting this problem.

Second, local markets, notably that of the North Dakota cities of Grand Forks and Fargo, are being ineffectively tapped. Foxfire Mountain continues to be viewed as a less desired choice for downhill skiing compared to what is offered at Buena Vista Resort near Bemidji and other Minnesota lake country ski facilities within a comparable distance as Foxfire Mountain for Grand Forks and Fargo. Other than the annual review of the summer dinner theatre of Foxfire Mountain that is printed in the Grand Forks Herald, there is little publicity generated on that part of the Rendezvous Region at the present time. It is more reasonable to develop eastern North Dakota as a source region than to attempt that with Winnipeg and Minnesota's Twin Cities.

Third, tourism facilities and trail signage are either unfinished or lacking. A major blow for stimulating tourism traffic for the Rendezvous Region occurred when the new State Historical Society of North Dakota museum at Pembina did not open as scheduled for the start of the 1995 summer tourism season. This magnificient facility, complete with an observation deck in its over 100-foot tower, remained unopened as of mid-January of 1996; if it is not opened by Memorial Day of 1996, there will be another delay in generating tourism dollars for the Rendezvous Region. Meanwhile, the lack of working capital for building up the infrastructure for the Rendezvous Region as a tourism area is reflected in even as small a matter as ameliorating the paucity of good signage for the Rendezvous Region Trail, a scenic drive-style loop that connects the cities of Walhalla, Pembina, Langdon, and Cavalier.

Finally, there is insufficient attention being paid to what could be the most valuable tourism resource of all for the Rendezvous Region: applied historical geography. Extreme northeastern North Dakota has significant archaeological sites that should remain undisturbed but could be better presented to the public to reflect the pre-1730s aboriginal settlement more completely. This would generate greater interest in the area by some potential tourists. Fur trade-oriented sites are reasonably well marketed to the casual summer tourist, but daylong school field trips during the spring and autumn are not being promoted among either K-12 educators or college/university educators. Furthermore, sites associated with late nineteenth century and early twentieth century commercial agriculture, post-1950s railway abandonment, and historic central business districts of communities within the region remain underutilized, if included at all, in tourism development projects.

Recommendations

There is no question that the Rendezvous Region presently has the potential to develop beyond a minor popular destination of tourists from throughout the greater region of North Dakota, Manitoba, and Minnesota. Until the marketing board and the various groups in the Rendezvous Region develop the necessary tourism infrastructure and associated advertising, however, it is highly unlikely that tourism will be a major revenue-generator in the two counties. From the standpoint of applied historical geography it appears that there are at least four significant contributions that professional geographers can make for helping the Rendezvous Region move along such a path of tourism development in a positive fashion.

First, there is a need for a comprehensive historic resources survey for the two county area which could be conducted as a public service for the marketing board and in consultation with the respective groups interested in this dimension of tourism. By identifying the sites that would be in a data base of historical geography landscapes, it would be possible to determine through consensus which sites might be considered as more important than others to receive more immediate attention for tourism development .

Second, once the comprehensive historic resources survey is completed with the key historical geography landscapes identified, it would be useful to develop either a pamphlet or field guide with substantial maps for the use of tourists when touring the two counties. The successful development of a prototype map in the summer of 1994 at the University of North Dakota as a professional courtesy to the Rendezvous Region's marketing board does provide a precedent for such cartographically-oriented documents (Figure 1).

Third, professional geographers should be working in close consultation with the marketing board for the Rendezvous Region to develop and to implement the concept of daytrips for school groups ranging from kindergarten to graduate level. Already, the GEOG 900 program of the University of North Dakota has experimented successfully with this effort as evidenced by positive feedback from participants in two quite different field trips conducted in academic years 1992-1993 and 1994-1995.

The final recommendation is to include applied historical geography as a "hook" for the older adult tourist market, especially in programs such as Elderhostels. Highlighting the fur trade with guided tours--complete with historical lifestyle demonstrations--could be done at times other than the annual Rendezvous Days weekend or Gingras Ox Cart Day. This would not only provide an opportunity for undergraduate and graduate geography majors to have internships and cooperative education experiences in tourism program development, but the multiplier effect of the revenues of such customized tourism packages would be felt in a variety of ways through the entire two county area.

Conclusion

As stated at the beginning of this paper, tourism is not a panacea for reviving the fortunes of depressed rural economies. Yet, it can and should be considered as a component in rural regional economic development (Gunn, 1994; Pearce, 1989). Such land use planning must be handled with care, however, otherwise the particular resources, be they scenic-climatic or cultural-historic, could be destroyed in the process (Murphy, 1989; Mieczkowski, 1995). Thus, it is imperative that future tourism planning for the Rendezvous Region incorporate concepts and principles of geographic-oriented tourism development as expressed in such standard treatises as those by Gunn (1994), Pearce (1989), and Murphy (1989) as well as address the general environmental issues of tourism and recreation of researchers such as Mieczkowski (1995).

It is especially germane to tourism planning for the Rendezvous Region that applied historical geography be incorporated into it. The notion that this highly scenic and exceedingly historically important part of not just North Dakota, but the Central Lowlands of North America, be developed without taking into account substantially the transformations of its cultural landscape through time is simply not acceptable from the viewpoint of a theoretician or a practitioner. Professional geographers who have specialties in historical geography can be making significant contributions to the future tourism planning for the Rendezvous Region, and in the same way the results of research associated with applied historical geography for the Rendezvous Region can provide valuable additions to greater geographical understandings of the making of the North American continent.

Bibliography

Bluemle, John, 1991. The Face of North Dakota. Revised Edition. Educational Series 21. Bismarck, ND: North Dakota Geological Survey.

Drache, Hiram M., 1970. The Challenge of the Prairie. Fargo, ND: North Dakota Institute for Regional Studies.

Gilman, Rhonda R., Gilman, Caroly, and Stultz, Deborah M., 1979. The Red River Trails. St. Paul, MN: Minnesota Historical Society.

Gunn, Clare A., 1994. Tourism Planning. Third Edition. Washington, D.C.: Taylor & Francis.

Hartje, Zelda,1995. Personal Conversations with the 1995 Rendezvous Region Festival

Co-Coordinator at Icelandic State Park during the First Annual Rendezvous Region Days on 10 June 1995.

Jackson, James A., 1970. The Centennial History of Manitoba. Toronto: McClelland and Stewart Limited.

Jensen, Debra K., 1994. "The Geography of the Rendezvous Region," unpublished GEOG 997 (Independent Study) Report, University of North Dakota.

Joslin, Mandy, 1992. Rendezvous Region. Draft Summary of Findings, Business and Tourism Planning Project, Phase 1. San Francisco: Retail Metrics Consulting.

Mieczkowsk, Zbigniew, 1995. Environmental Issues of Tourism and Recreation. Washington, D.C.: University Press of America.

Murphy, Peter E., 1985. Tourism: A Community Approach. New York: Methuen.

Narloch, Randal L, 1981. "Sunflower in North Dakota: A Spatial Diffusion Analysis," unpublished master's thesis, University of North Dakota.

Pearce, Douglas, 1989. Tourist Development. Second Edition. New York: John Wiley and Longman Scientific and Technical.

Ray, Arthur J., 1974. Indians in the Fur Trade. Toronto: University of Toronto Press.

Schneider, Mary Jane, 1990. North Dakota's Indian Heritage. Grand Forks, ND: University of North Dakota Press.

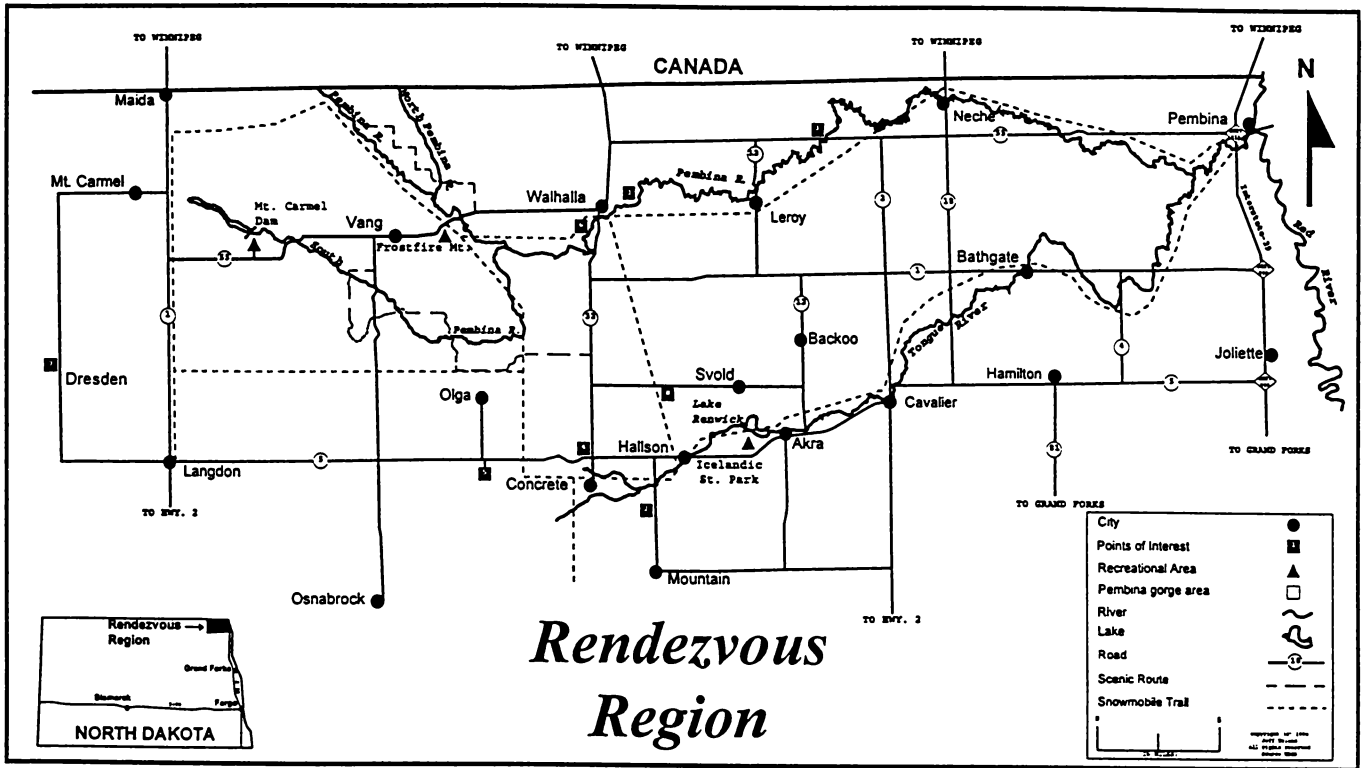
Scott, G. A. J., 1995. Canada's Vegetation: A World Perspective. Montreal: McGill-Queens University Press.

Stradley, Scot A.,

1981. A Staple Perspective on Economic Development in North Dakota. North Dakota Economic Studies 28. Grand Forks, ND: Bureau of Business and Economic Research, University of North Dakota.

1994. The Broken Circle: An Economic History of North Dakota. Grand Forks, ND: Flat Earth Press.

Tweten, Jerome D. and Jelliff, Theodore B., 1976. North Dakota: The Heritage of a People. Fargo, ND: North Dakota Institute for Regional Studies.



POINTS OF INTEREST AND HISTORICAL SITES

- GINGRAS TRADING POST*
- CAVALIER AIR FORCE STATION
- PATON ISLE OF MEMORIES
- OAK LAWN CEMETARY
- SENATOR YOUNG DAM
- KITTSON TRADING POST
- CAVALIER COUNTY MUSEUM
- JAY WESSELS WILDLIFE AREA

IN BATHGATE
ST. ANTHONY'S CHURCH
PIONEER REST HOME
NORVAL BAPTIE MONUMENT

IN CAVALIER
PEMBINA COUNTY COURTHOUSE*

AT ICELANDIC STATE PARK
PIONEER HERITAGE CENTER

IN LANGDON
ARCHITECTURE MUSEUM

IN MOUNTAIN
VIKUR CHURCH

IN NECHE
PFC HENRY GURKE MONUMENT

IN PEMBINA
NORTH DAKOTA STATE MUSEUM

IN WALHALLA
MARTYR'S GRAVES

* ON NATIONAL REGISTER OF HISTORIC PLACES

Figure 1. Map of the Rendezvous Region produced as a sample in 1994 to demonstrate how the University of North Dakota Geography Department could help the tourism marketing board of the Rendezvous Region.

STRATEGY for RECRUITING UNIVERSITY STUDENTS at a TIME of DECLINING HIGH SCHOOL GRADUATES

Mohammad Hemmasi
Department of Geography, University of North Dakota, Grand Forks, ND 58202

University enrollment numbers fluctuate in response to the interplay of many demographic, socioeconomic, and geographic factors. The latest national-level data show significant variations in the number of high school graduates who enrolled in the institutions of higher education during the fall of 1992. In that year, the number of first-year college students declined in twenty-two states and increased in twenty-eight states (5). New Jersey (18,462)and Illinois (7,310) lost the most, while North Carolina (8,627) and Massachusetts (7,500) were the top gainers. North Dakota gained 1,490 students more than it lost in 1992. As a result many institutions of higher education are under pressure to step up their efforts to increase their enrollment and to retain their present level of student population. A myriad of complex factors are responsible for the decline of the college student body, especially the freshman class in some states. First, a state's general population decline through outmigration plays an important role in this process. Second, norms of higher age-at-first marriage, lower population fertility rate, and smaller family size, are contributing factors. Third, a state's economic status, unemployment rate, and family income also influence the college entrance rate. Finally, a drop in the international students admission may effect some universities. On the other hand, a higher proportion of women enter colleges than in the past and some older-than-average students, who finished high school years ago, come back to school now.

In North Dakota the number of public high school graduates has declined from 11,307 in 1965 to 8,862 in 1995, a loss of more than 21% in three decades. The highest number of high school graduates was 12,215 in 1976-77. Considering this shrinking number of high school graduates, the North Dakota institutions of higher education are seriously competing for new students and trying to retain them once entered the university system. The University of North Dakota (UND), for example, has grown from 1,682 in 1935 to 11,512 in 1995. The highest number of students registered was 12,438 in 1992, but it has declined ever since. A halt in this process led President Kendall Baker to say that he was "extremely pleased" that UND's enrollment topped 11,500 again in 1995. "This is exactly what we worked very hard all year to do. An awful lot of folks did an awful lot of hard work to make this happen." (7). Universities usually have a special recruiting unit with experienced personnel, often aided by task force groups, consisting of faculty, students, community members and alumni to attract new students. This study presents a methodology and results of a preliminary analysis aimed at identifying the areas that should be the focus of university recruitment, and the areas that must try to maintain its favored status. We also discuss a host of crucial factors that may enter the students' decision-making process in selecting a specific school. Use of the gravity model in studies of spatial interactance has shown that the model is helpful in predicting flow of students to a university site (3,4,6).

Data and Methodology

The data for this study were collected and provided by the North Dakota Department of Public Instruction, North Dakota University System, and the University Alumni Office. The information analyzed, at this stage, included the number of public high school graduates, first-year college students (freshmen) enrolled in a university, shortest highway distance between the county seat of each county to the city where a university is located, and the intervening opportunities. The latter is measured by adding the number of institutions of higher education that are closer to the resident county of a student than the university of choice. The highest number of these opportunities is eleven for some extreme western counties and as low as one for some others.

Methods of analysis include the application of unconstrained and constrained gravity models, and least square regression technique (1,2). The Newtonian gravity force in its simplest form is: $I = G\,(m_1 m_2)/(d_{12})^2$. Here we modify it to: $I = k\,(P_1 P_2)\,/\,(d_{12})^b$ where I is the actual number of freshman college students from each county, P_1 and P_2 are the number of high school graduates in the origin and destination counties in the same year, d_{12} is the shortest road distance between the county seat and the university site, k and b are constants. The parameter k is a constant partly determined by the units in which the variables are measured. When it is applied to social problems, the power 2 may take other values (b) depending on the severity of the distance deterrence or its attenuation effect. In an unidirectional spatial interaction such as migration of students to a university town we drop P_2.

$$I = kP_1 / (d_{12})^b \quad \text{or} \quad I/P_1 = k / (d_{12})^b$$

By taking the logarithm of both sides we change the above equation to a linear function in the form of

$Y = a + bX$. $\log(I/P_1) = \log k - b \log d_{12}$

Through application of a least square regression technique to the last equation we generate the parameters k and b for

the specific data set under study. Solving the above equation by using the values of k and b, we calculate E" or the expected number of students to enroll in the university from each county in that year. For example if:
$E = I / P_1$, then for UND,
$\log E = -0.9064 - 0.4471 \log (d_{12})$; E' = Antilog (logE);
$E'' = (E' \times P_1)$; $R = (I - E'')$; The sum of the predicted values generated by the above unconstrained gravity model often vary from the actual number of students involved ($\sum I \# \sum E''$). In this instance, since we know the total enrollment at a university, an attraction-constrained gravity model is most appropriate.

$$CE'' = ((E'' / \sum E'') \times \sum I).$$

In words, CE" ensures that the total expected enrollment at a university equals the actual total enrollment. The ultimate goal is to identify counties that contribute less (or more) students than is expected. The difference between actual and predicted enrollment is termed a residual (R) and can provide information on student enrollment from a particular county ($CR = I - CE''$).

Analysis

The same analysis was performed for the three major higher educational institutions: University of North Dakota (UND), North Dakota State University (NDSU), and Minot State University (MiSU). In the fall of 1995, they enrolled 3,505 or 47% of all the high school graduates who chose to go to college in North Dakota. The two largest universities, NDSU and UND, attracted freshman students from fifty counties each, a clear indication of their prominent positions in the higher educational system of the State. However, only students from 32 counties attended MiSU in 1995. So the catchment area of MiSU was far more limited than the other two (Figure 1). The regression and correlation results show several interesting points (Table 1). First, the coefficients of determination between proportion of students enrolled in each university ($\log I/P_1$) and distance ($\log d_{12}$) is negative and significant, yet with notable variations among them. Likewise, the regression coefficients (b) are negative and significant. Despite the apparent overall convergence, the strengths of the parameters vary among them (i.e., NDSU: b=-.2890; UND: b=-.447 MiSU: b=-2.227). The Intervening Opportunities (IO) index exerts a greater deterrence for NDSU and UND than MiSU. Statistically significant positive relationships were found between the actual number of freshmen (I) and predicted (CE") number of students in all the models (Table 1).

The practical use of this study is that it identifies places where heavy recruiting is necessary to attract students (Table 2). The results show the expected number of students from each county based on their potential for contribution as measured by the total number of high school graduates and the distance which separates them from the university site. In other words, the residuals are the number of students who did not enroll or exceeded the expected target after the effect of population and distance was removed. Further research on the nature and strength of other factors remains to be done in the future.

Table 2 lists counties that over predicted (-) and under predicted (+) at least five freshmen in each university's student body in 1995. In the case of UND, nine counties: Grand Forks (63), Burleigh (17), Ward (12), Walsh (12), Mountrail (10), Mercer (7), Ramsey (6), Wells (5), and Bottineau (5) sent 137 students more than expected. Most of these counties are north-northwest of Grand Forks, away from the competition of other universities along highway I-94. On the other hand, five counties were under represented at UND. Cass county, the site of NDSU, UND's main rival, fell short by 53 students. Others in this category were, Richland (15), Morton 11), Stutman (10), and Traill(8), all of which have access to a college within their commuting distance. Overall, the ratio of over predicted to under predicted counties was 28:25. A similar pattern of over and under predicted counties emerged for NDSU. Ten counties sent 159 students more than predicted and ten failed to contribute for a total of 153 students. Cass county sent 98 first-year students more than predicted by our origin-constrained gravity model, while the remaining nine counties failed to contribute by an average of seven students each. The ratio of residuals of over predicted (-) to under predicted(+) was 21:24. Ten counties fell short of contributing the expected number of students to NDSU. Grand Forks county led them by 50 students, followed by Ward (22), Morton (17), Williams (12), Ramsey (11), Burleigh (10), Barnes (10), Nelson (7), Rolette (6), and Sioux (6). Most of these counties also have easy access to alternative colleges.

The pattern of residuals for MiSU differs from the two larger universities. Only five counties sent a total of 73 students to MiSu beyond the predicted number. They include Williams (22), Bottineau (16), Rolette (16), Ward (11), and Divide (8). These counties are all located north and northwest of the state where MiSU is the only leading four-year university. Among the eight counties where MiSU did not fair well by 64 students, Burleigh and McLean led the way by 15 and 12, respectively. Perhaps partly because of its geographic size and elongated shape, Ward County, unlike others, did not

TABLE 1. RESULTS of the ANALYSIS of UNIVERSITY ENROLLMENTS, FALL 1995

University	Regression Equation	N	r	r^2
UND:	$\log I / P_1 = -0.9064 - 0.4471 \log d_{12}$	50	-0.598	0.358*

Correlation matrix

	I	CE"	E	LD	IO
I	1.00	.989*	.891*	-.751*	-.311**
CE"		1.00	.843*	-.746*	-.306**
E			1.00	-.799*	-.466*
LD				1.00	.793*
IO					1.00

NDSU: $\log I / P_1 = -\ 0.2766 - 0.2890 \log d_{12}$

50 -0.433 0.187*

Correlation matrix

	I	CE"	E	LD	IO
I	1.00	.988*	.609*	-.780*	-.346*
CE"		1.00	.533*	-.771*	-.349*
E			1.00	-.594*	-.325**
LD				1.00	.798*
IO					1.00

MiSU: $\log I / P_1 = 3.264 - 2.227 \log d_{12}$

31 -0.753 0.567*

Correlation matrix

	I	CE"	E	LD	IO
I	1.00	.997*	.846*	-.480*	-.134
CE"		1.00	.830*	-.478*	-.122
E			1.00	-.737*	-.306**
LD				1.00	.351*
IO					1.00

Calculated by author. * $p<0.01$; ** $P<0.05$.

emerge as the leading contributor to MiSU. To account for the unusual shape and large size of Ward County, its intra county distance was set at a higher level than Grand Forks and Cass.

The spatial distributions of counties with highly under/over predicted student numbers imply that besides distance and population, intervening colleges (IO) seem to play a role in the process. The hypothesis is that high school graduates, every thing else being equal, would prefer to attend a college closer to their home than those farther away. The importance of IO is shown by a statistically significant negative correlation between proportion of the county high school graduates who enrolled in a university and number of the intervening opportunities (Table 1). It would have been preferred to run a multiple regression model including both distance and IO in the same equation. However, because of a statistically significant positive correlation between distance and IO Index, it would have violated the assumption of "independence" of explanatory variables. Fine tuning of the model is possible through consideration of better measures of distance, and use of additional relevant variables. Future works should also include the counties of neighboring states, where because of reciprocity agreement many student exchanges are taking place.

Conclusion

The interplay of a host of factors leads to a short fall in the number of university students in many states. Lower fertility rates, interstate migration, reciprocity agreements, lower number of foreign students admitted, and economic health of a state seems responsible for the current situation. As a result universities are compelled to pay greater attention to their recruitment strategies and seek ways to retain those already admitted. It is important to be able to decide, with a high degree of accuracy, the places where a university needs to recruit rigorously, and also nurture areas that have traditionally favored it.

This study showed that the gravity model is an effective methodology to assess the spatial interaction between places. An application of it to the analysis of student flow data to the three largest North Dakota universities helped to show the counties that do not contribute to the level that one would expect based on their number of high school graduates and the distance separating them from the university. Consistently strong correlation coefficients were found between the actual and expected number of freshmen students who enrolled in these three case studies. For example, UND must reach out to counties such as Cass, Burleigh, Richland, Morton, and Stutman.

Of course, the complex problem of duplication in providing higher education opportunities to a declining population base remains to be resolved. Other possible variables that should be investigated include the range and nature of degrees offered, "alumni stock" in a county, high school teachers/counselors knowledge of the educational opportunities offered at a site, and family income. Yet, distance is apparently one of the most important variables to be investigated while searching for answers to the question of why students prefer one school to another.

References

1. Fotheringham, A. S. and M. E. O'Kelly. 1989. Spatial Interaction Models: Formulations and Applications, Boston: Kluwer.
2. Haynes, K. E. and A. S. Fotheringham. 1984. Gravity and Spatial Interaction Models, Beverly Hills: Sage.

3. Kariel, H.G. 1968. "Student Enrollment and Spatial Interaction'" Annals of Regional Science, Vol. 2, pp.114-126.
4. McConnell, Harold. 1965. "Spatial Variability of College Enrollment as a Function of Migration Potential," The Professional Geographer, Vol. 17-6, pp. 29-37.
5. North Dakota State Data Center. 1995. "North Dakota High School Graduates, 1969-70 to 1993-94 and North Dakota Residence and Migration of College Freshmen, Fall 1992," The Economic Briefs, Vol. 4 -10, pp. 1-2.
6. Stewart, John Q. 1941. "The 'Gravitation,' or Geographical Power of a Collage,"Bulletin of the American Association of University Professors, Vol. 27, pp. 70-75.
7. University Letter: U. of North Dakota, Vol.35-5, September 22, 1995.

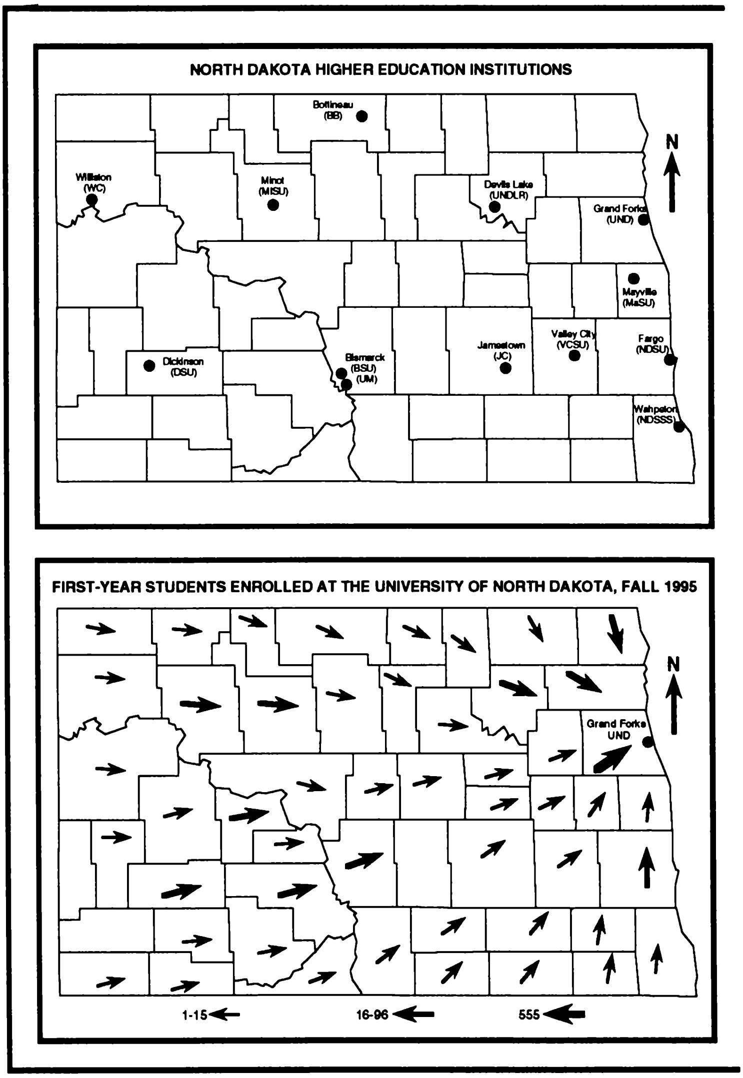
TABLE 2. ACTUAL, EXPECTED, and RESIDUAL of FRESHMAN STUDENTS ENROLLMENT, 1995*

		UND			NDSU			MiSU		High School
County	I	CE"	CR	I	CE"	CR	I	CE"	CR	graduates
Barnes	13	17	- 4	16	26	- 10	0	2	- 2	164
Bottineau	13	8	5	6	10	- 4	27	11	16	100
Burke	3	3	0	13	4	9	11	7	4	46
Burleigh	45	62	17	82	93	- 11	26	41	- 15	824
Cass	96	149	- 53	602	504	98	3	9	- 6	1187
Dickey	10	6	4	16	9	6	0	1	- 1	72
Divide	5	2	3	3	2	1	9	1	8	35
Emmons	2	5	- 3	15	8	7	0	1	- 1	70
Grand Forks	555	492	63	61	111	- 50	1	9	- 8	755
Grant	4	2	2	9	4	5	0	10	- 1	35
Griggs	7	7	0	13	8	5	0	1	- 1	55
McLean	15	15	0	23	21	2	14	26	- 12	191
Mercer	18	11	7	12	16	- 4	16	13	3	153
Morton	17	28	- 11	24	41	- 17	11	17	- 6	371
Mountrail	18	8	10	9	11	- 2	22	26	- 4	116
Nelson	12	10	2	2	9	- 7	1	2	- 1	74
Ramsey	28	22	6	10	22	- 12	1	7	-6	183
Ransom	6	9	- 3	20	14	6	0	1	- 1	95
Renville	7	5	2	4	7	- 3	17	23	- 6	69
Richland	4	19	- 15	36	31	5	0	1	- 1	194
Rolette	13	15	- 2	12	18	- 6	23	7	16	170
Souix	2	4	- 2	0	6	- 6	0	1	- 1	60
Stark	24	23	1	31	36	5	2	7	- 5	359

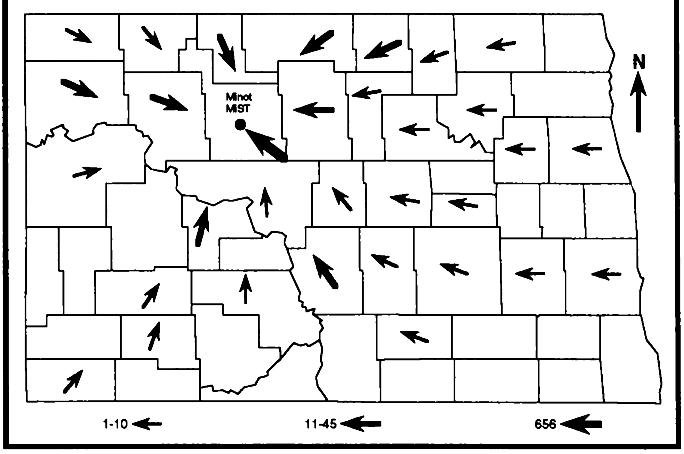
Stutman	14	24	- 10	32	35	3	2	5	- 3	253
Traill	14	22	- 8	20	22	2	0	1	- 1	127
Walsh	44	32	12	32	24	8	0	2	- 2	187
Ward	70	58	12	51	73	- 22	656	645	11	710
Wells	11	6	5	12	7	5	7	5	2	63
Williams	21	19	2	14	26	- 12	32	10	22	284

*Counties with at least five students over(-) or under(+) predicted in any university.
I = Freshman students; CR" = Predicted; CR = I - CE";

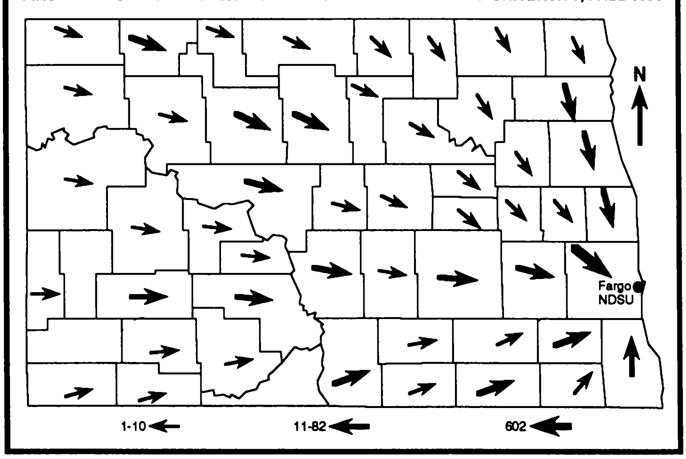
Format changed for printing.\RGG


NORTH DAKOTA HIGHER EDUCATION INSTITUTIONS
Bottineau (BB)
Williston (WC)
Minot (MISU)
Devils Lake (UNDLR)
Grand Forks (UND)
Mayville (MaSU)
Valley City (VCSU)
Fargo (NDSU)
Jamestown (JC)
Dickinson (DSU)
Bismarck (BSU) (UM)
Wahpeton (NDSSS)
N
FIRST-YEAR STUDENTS ENROLLED AT THE UNIVERSITY OF NORTH DAKOTA, FALL 1995
Grand Forks UND
N
1-15
16-96
555

FIRST-YEAR STUDENTS ENROLLED AT MINOT STATE UNIVERSITY, FALL 1995



FIRST-YEAR STUDENTS ENROLLED AT NORTH DAKOTA STATE UNIVERSITY, FALL 1995



STATUS OF GIS IN NORTH DAKOTA'S K-12 INSTITUTIONS

Chandra S. Balachandran
Department of Geosciences, North Dakota State University, Fargo ND 58105

INTRODUCTION

Geographic Information Systems [GIS] are computer-based systems which allow the rapid and meaningful gathering, processing, retrieval, and display of information that is geographically referenced. GIS are increasingly being used in a wide variety of analytical tasks such as environmental monitoring, analysis of voting patterns, and emergency care delivery. Many colleges and universities around the world expose students to GIS techniques and technologies as part of many curricula (Walsh, 1992).

GIS are a form of implementation of geographic principles, and offer a very powerful vehicle for interdisciplinary thinking skills for students. Because of this, they are also important tools for (1) integrating knowledge students gain from different disciplines which they can then bring to bear upon problem-solving, and (2) delivering education on the applications of geography to real-world problem-solving.

As such skills are useful in a wide variety of disciplinary training, college and university graduates who have acquired them have an added advantage in their search for jobs or higher studies. This will be true not just because of computer-based skills of these graduates, but also because they will bring integrative critical thinking skills which they are able to operationalize for problem-solving.

As higher education continues to expand its inclusion of GIS in various parts of its educational structure, it is becoming increasingly important that students in K-12 institutions begin exploring these technologies as well. This population, already exposed to the possibilities which GIS offer, will form a more technologically competent freshman population when they arrive on college/university campuses. This technological savoir-faire indicates a more fundamental skill: the integrative, critical pedagogical skill in students.

With these in mind, North Dakota State University [NDSU] has been involved in the introduction of GIS for K-12 education in North Dakota. The remainder of this paper is organized into the following sections:

- history of GIS education at NDSU in the overall context of GIS at NDSU,
- history and status of GIS for K-12 education in North Dakota, and
- future directions for this effort.

HISTORY OF GIS EDUCATION AT NDSU

Following an initiative undertaken by the Governor George Sinner of North Dakota, an ad-hoc Task Force on GIS was formed in the late 1980s and included several Government agencies and educational institutions. NDSU became involved in this effort in 1989 as part of its institutional missions as a land grant university. As part of this involvement, NDSU sought support for GIS equipment, personnel, and software. In 1991, the Department of Geosciences decided to include GIS education as part of its efforts to hire a geographer. In 1992, IBM donated three work stations — a RS/6000 model 560 and two model 220s. In the same year, a

UNIX Arc/Info lab kit was acquired from Environmental Systems Research Institute, Inc. [ESRI] (Balachandran and Watt, 1994).

GIS at NDSU is composed of three broad components (Figure 1). Under the teaching component, since 1993, an introductory GIS course has been offered for graduates and undergraduates with increasing enrollments and demand. This course represents one aspect of the overall GIS education effort at NDSU. In recent years, several graduate students have started including GIS as a tool for their research work.

If GIS education at NDSU, and indeed in North Dakota as elsewhere, is to prosper and grow, it is important that students gain exposure to GIS as tools of understanding and analysis at earlier stages in their education. Therefore, NDSU undertook a phased effort to deliver GIS education to the K-12 institutions via a partnership among several entities in North Dakota (Figure 2). This effort is also in keeping with the missions and goals of NDSU in becoming a node for K-12 GIS education in North Dakota. The context for GIS at NDSU is shown in Figure 3.

K-12 GIS EDUCATION IN NORTH DAKOTA

History

In 1993, under an Eisenhower Grant for science education, one short course was offered on the use of GIS. This short course elicited considerable enthusiasm among the attendees who, though few in number, represented geography, earth science, botany, and chemistry. The partnership for K-12 GIS education (Figure 2) and the outreach program have continued to grow. Table 1 shows a summary of the progression of courses offered to K-12 GIS education North Dakota. Each year, the course has expanded in length, coverage, and participation. Under the K-12 GIS education partnership, each school represented in the courses in 1994 and 1995 received a site-licensed copy of Arcview™, a desktop GIS viewing software package produced by ESRI.

The courses continue to be complemented by presentations on GIS for K-12 education by K-12 teachers and this author at various forums in North Dakota.

In 1996, grant from the North Dakota Department of Public Instruction under the Title II Eisenhower funds is supporting the offering of the K-12 GIS course to include Science, Mathematics, and other teachers. This course will be 2 weeks long with expanded coverage.

Status

At the time of preparing this paper, schools represented in the 1994 and 1995 courses, both of which were covered by the K-12 GIS education partnership have received site-licensed copies of Arcview software. Teachers in these schools are working to set up the software on computers and to gain more experience with the software prior to introduction into their teaching.

In September 1995, an electronic mailing list has been established to facilitate discussions among those who are interested in K-12 GIS education. Every teacher who uses SENDIT can subscribe to this list. It is growing steadily and will soon be a major network for exchange of ideas and information. The list is currently minimally active. As teachers explore GIS beyond manuals and tutorials, this list is expected to become more active.

Interest in the course continues to grow and inquiries from schools around the State. This growing interest resulted in the submission of a proposal to the North Dakota Department of Public Instruction for Title II Eisenhower Funds to not only support offering of the course in 1996, but also to achieve two other goals: (1) to recruit science and mathematics teachers in addition to geography teachers state-wide, and (2) to support follow-up outreach efforts including the setting up of regional K-12 GIS education centers. These two additional goals represent the next phase of the K-12 GIS endeavor. The four regional centers to be established are:

1. Red River High School, Grand Forks,
2. Minot Public Schools, Minot,
3. Bismarck Public School District # 1, and
4. Benjamin Franklin Junior High School, Fargo.

Teachers from under-represented areas of the State are being specifically targeted for recruitment. In addition, science, mathematics, and geography teachers from the four regional centers are being recruited for the 1996 course. These teachers will become regional leaders in the inclusion of GIS in K-12 education in North Dakota.

The present author, with a teacher mentor involved in the planning and presentation of the course, will travel to these regional centers and other selected K-12 institutions in North Dakota for follow-up presentations.

Outlook

As interest in GIS as an educational tool in North Dakota's K-12 curriculum grows, the partnership of private and public agencies will continue to support it. Skills in using GIS technologies, techniques, and approaches have, for our students, the pedagogical importance of inculcating the interdisciplinary approach to problem-solving, and the practical importance of ability to compete better in the job market. In addition, the implications of geographic understanding in the context of various issues will become clearer. This will result in, among other things, greater flow of knowledge and educational delivery among higher education institutions and K-12 institutions in North Dakota.

REFERENCES

Balachandran, C.S., and Watt, D.L. (1994) "The Geographic Information Revolution for the College Curriculum." Small College Computing Symposium, MN, p. 70-75.

Walsh, S.J. (1992) Spatial Education and Integrated Hands-on Training: Essential Foundations of GIS Instruction. Journal of Geography, 91(2), p. 54-61.

Table 1: History of GIS courses for K-12 teachers in North Dakota. The interest in K-12 GIS education continues to grow with wider areas and more diverse subjects being represented at the annual courses.

Year	Course length	# of teachers	Schools represented	Subject areas of teachers
1993	5 half-days	4	Fargo North; Bismarck High; Perham Middle, MN; Carrington High.	Chemistry; Adv. Biology; Gen. Science; Geography.
1994	3 full days	24†	W. Fargo; Fargo Public; Moorhead Sr. High; Grand Forks Public; Ellendale; Verona Public; Grand Forks Central; Fort Berthold Community; Hazen Public; Minot Public; Munich Public; Schroeder Jr. High; Hope.	Geography; Social Studies; Economics; History; English; Biology; Environmental Science; Earth Science; Civics.
1995	5 full days	20‡	Our Redeemer's, Minot; Lincoln; Velva Public; Oak Grove Lutheran, Fargo; Wyndmere High; Mayville State U.;Milton-Osnabrock; Casselton; Cass Valley North; West Fargo Public; Hazen Public; Starkweather Public; Midway; J.T. School Dt., Woodruff, WI.	Social Studies; Geography; History; Political Science; Geology; Meteorology; Biology; Civics; Earth Science; Life Science; Language; Arts.

† In addition, there were 3 pre-service teacher candidates and 1 school administrator.
‡ In addition, there were 2 administrators.

Figure 1: The components of GIS at NDSU.

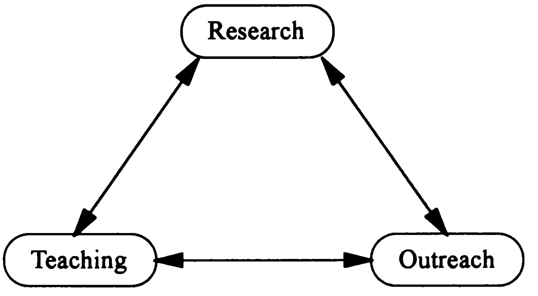


Figure 2. K-12 GIS education partnership in North Dakota

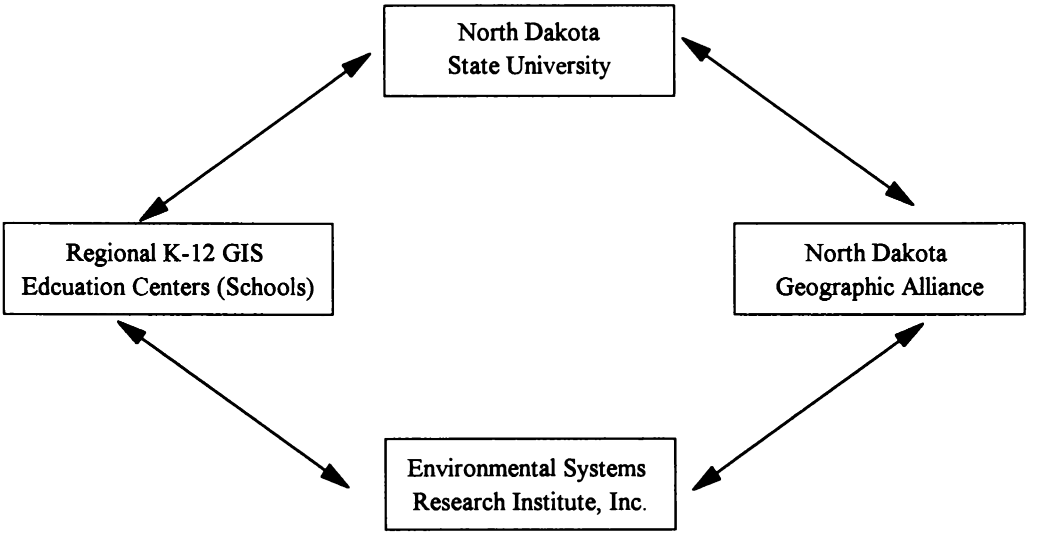
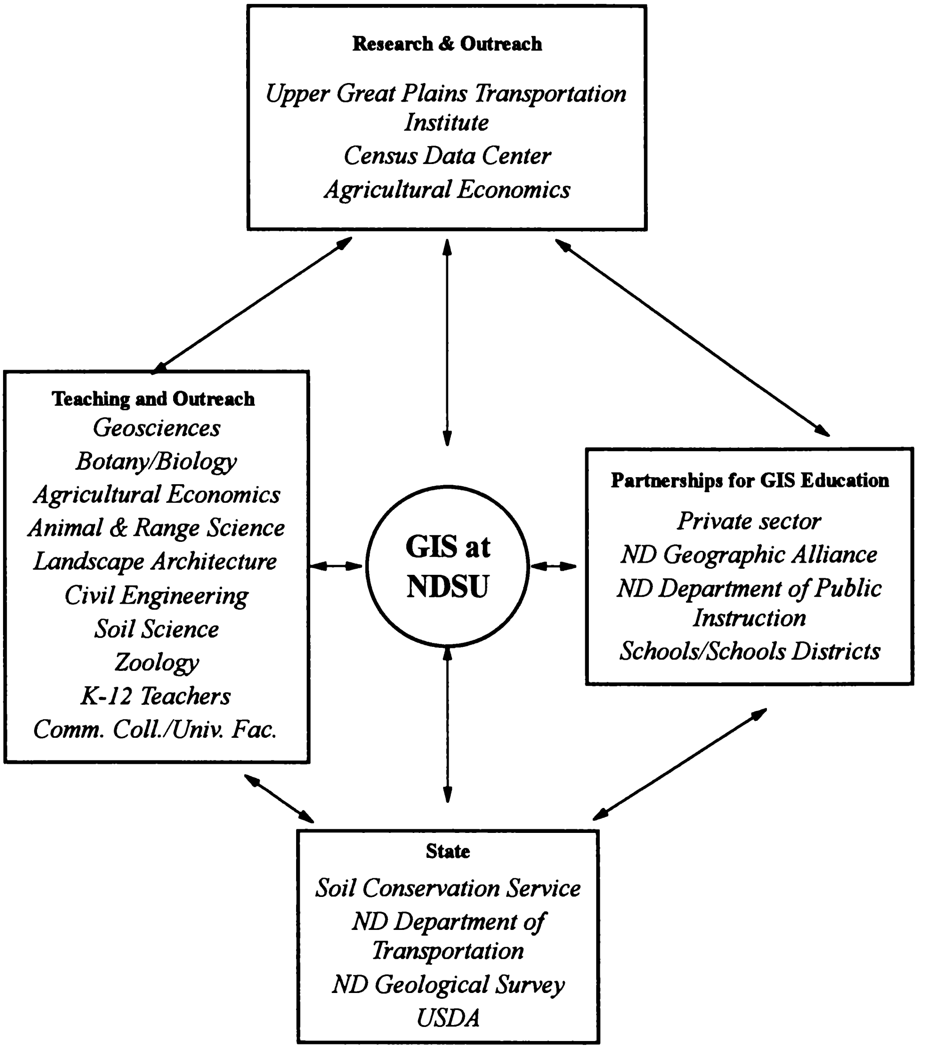


Figure 3. GIS at NDSU: The partnerships among various organizations support GIS education at NDSU. The endeavor's components and the main constituencies served are shown.



GEOGRAPHIC INFORMATION SYSTEM in GRAND FORKS

Floyd Hickok
GIS Director Grand Forks - East Grand Forks MPO

In 1991 Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA). It recognized the importance of GIS in transportation planning and provided funding to states and Metropolitan Planning Organizations (MPO) for its development. MPOs are funded by US Department of Transportation with the mission of transportation planning. Metro areas over 50,000 population are eligible. ISTEA has made GIS possible in many of the Nation's smaller metro areas. Without it Grand Forks would have little or no GIS.

In early 1993 the MPO hired a GIS Director and the work of developing a geographic information system for Grand Forks and East Grand Forks began. In the mid 1980's the City Engineering Department began creating plat maps in AutoCad, so GIS had a considerable head start. Nevertheless, it has taken three years to make the first parts of the GIS operational.

The geography database was first developed as sixteen AutoCad files, each being a separate section of the city. Each area was separated from adjacent areas by the width of a street right-of-way. AutoCad is a powerful drafting program, but has little GIS capability. ArcCad is an add-on to AutoCad witch gives it GIS functionality. Our primary use for ArcCad is for converting AutoCad drawings into ArcInfo coverages. ArcCad was then used to clean, build and error check each area one at a time. Each area was small enough that even the most time-consuming operations only took a few minutes to execute. Then the time came to combine them into a single file. The City of Grand Forks has 14,026 properties. When all of these were in one file, some operations took hours in stead of minutes. And ArcCad complained that a polygon had more than 5,000 arcs. No property has that many points. But all ArcInfo coverages have one universal polygon. All street right-of-ways are interconnected and open, so every property that touched a street or alley was a part of the universal polygon. This included nearly every property. To solve this problem, all right-of-ways were closed off at the city limit, so that the universal polygon was restricted to properties on the edge of the city. The right-of-way polygon had to be subdivided into numerous polygons in order to avoid the 5,000 arc limit. This was done according to their functional classification. This solved the universal polygon problem. On a 100 MHz Pentium computer with 32 MB of RAM it takes ArcCad five hours and 200 MB of temporary disk space to convert the AutoCad file into an ArcInfo coverage for properties.

ArcView 2.1 is being used for most GIS operations. ArcView is much cheaper and more user friendly than ArcCad. However, ArcView has very limited capacity for creating geography databases. ArcView can utilize ArcInfo coverages or convert them to shape files. Shape files operate much faster than coverages. It takes about seven minutes to display the 14,026 properties in ArcInfo coverage format, but only 40 seconds to display the same area as a shape file.

Because the mission of the MPO is transportation planning, the GIS was designed primarily for that purpose. But GIS is used for a wide variety of other uses. One common use in a planning office is for notifying property owners of proposed zoning changes. Typically all owners within 400 feet must be notified. GIS is ideal for this purpose. It is a simple matter of selecting the properties which are included in the proposed change and then asking GIS to expand the selection to include all properties which have any part within the specified distance of the original set. It generally only takes a few seconds and the list is compiled, complete with owners names and addresses ready to be sent to the printer. Another use is floodplain management. In order to have the lowest possible flood insurance rates, it is necessary to maintain records of properties and structures in the flood plain. GIS provides a very efficient means of determining which properties are in the floodplain.

One major aspect of transportation planning is traffic modeling. The Grand Forks metro area is divided into about 200 Traffic Analysis Zones (TAZ). Trip Generation Rates are used to estimate number of trips beginning and ending in each TAZ. Each kind of housing unit and each kind of land use has its own generation rate. GIS is used to determine the number and kind of housing units and the amount of land area devoted to various uses. Accurate and up-to-date land use data important to many GIS applications. Figure 1 shows a generalized land use map of a part of southwestern Grand Forks. The under lying database contains a much more detailed land use scheme.

Another transportation related use is pavement management. Information about the type, width, condition, age, etc. of each segment of pavement is maintained and can be displayed in any desired combination. Another use is in traffic accident monitoring. Figure 2 illustrates only one of the endless ways this information can be viewed. There were no alcohol related fatalities in the two year period. The map shows that there was a high concentration of accidents on some principal streets and very few on others.

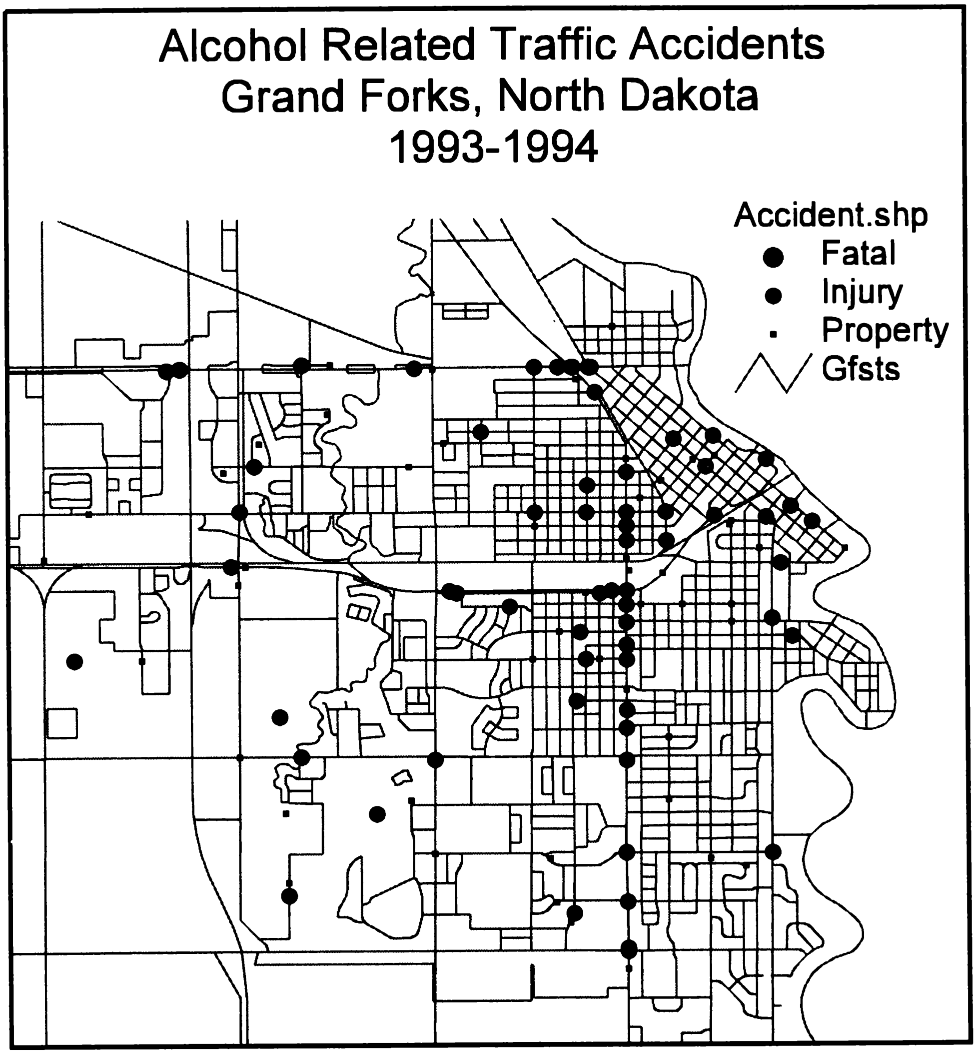
The data can be displayed by time of day or day of week. This is valuable to law enforcement for determining when and where to deploy its limited resources. Engineers can use this as a tool for identifying needed engineering improvements such as turning lanes or traffic signals.

At times it seems like progress is slow, but GIS development has progressed faster in Grand Forks than many other places. Fargo and Bismarck started about a year before Grand Forks, but are not as far along. Grand Forks has done all work in-house. Fargo and Bismarck have relied heavily on consultants and contractors.

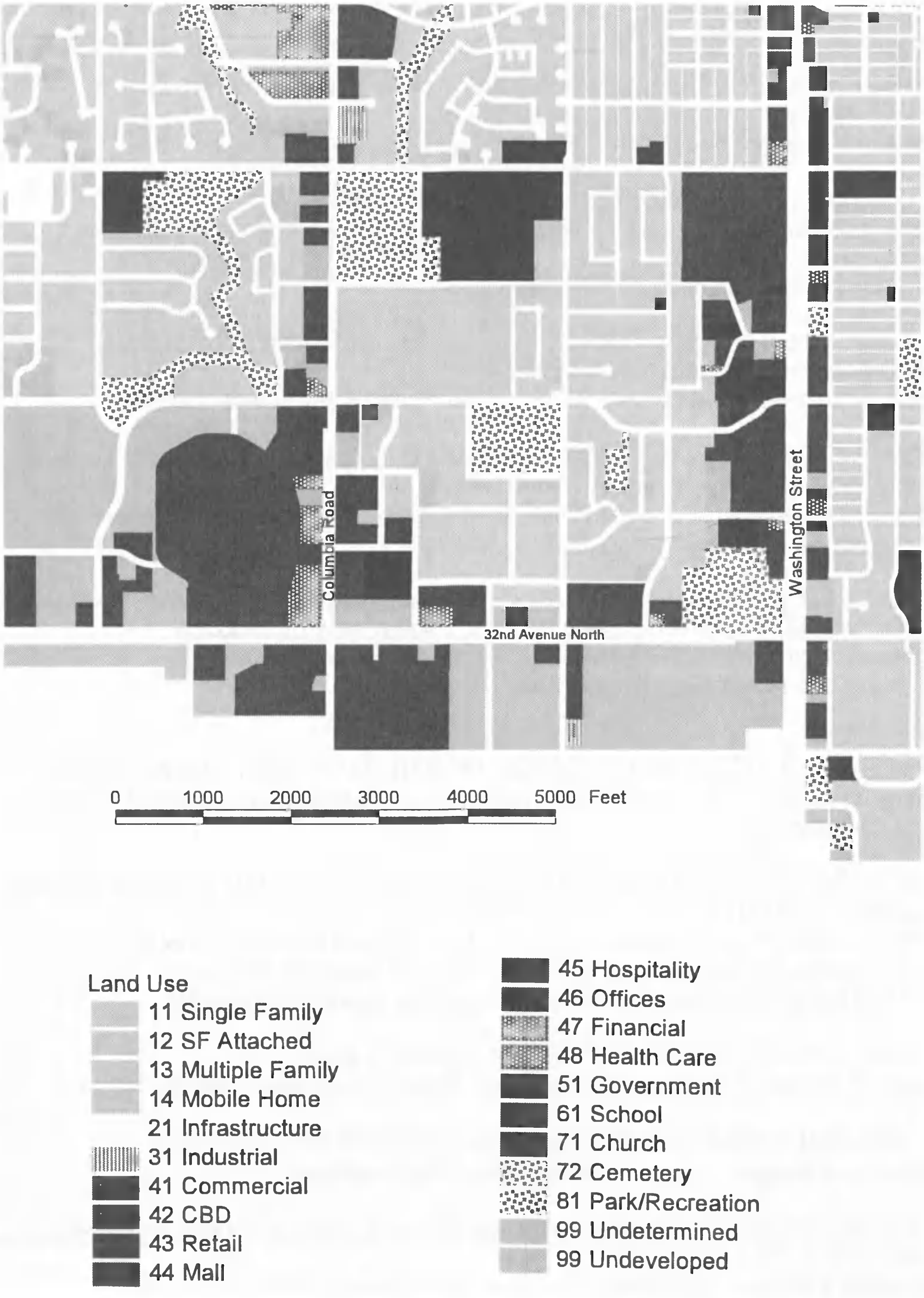
Hardware and software are improving at an astonishing rate. Much of the capability now available did not exist just three years ago when GIS development started in Grand Forks. Therefore, a progress report, such as this, is out-of-date long before it is published. That is what makes this an exciting and challenging time for GIS.

Format changed for printing.\RGG

Figure 2.



Southwest Part of Grand Forks,



ECOLOGICAL STUDIES at the WOODWORTH STUDY AREA

A Symposium Organized by: **Ned H Euliss**, Jr
Northern Prairie Science Center, Jamestown, North Dakota 58401

Friday, 26 April, 1996 Valley City, North Dakota

8:20 ECOLOGICAL STUDIES at the WOODWORTH STUDY AREA, NORTH DAKOTA: SESSION OVERVIEW and OBJECTIVES
Ronald E Kirby and **Ned H Euliss, Jr***, Northern Prairie Science Center, Jamestown

8:40 An INTRODUCTION to the WOODWORTH STUDY AREA
Douglas H Johnson*, Kenneth F Higgins, Robert O Woodward, Northern Prairie Science Center, Jamestown and South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Brookings

9:00 IMPACT of AGRICULTURE LAND-USE on PRAIRIE WETLAND ECOSYSTEMS: EXPERIMENTAL DESIGN and OVERVIEW
Robert A Gleason* and Ned H Euliss, Jr, Northern Prairie Science Center, Jamestown

9:20 SPATIAL and TEMPORAL VARIABILITY of WATER QUALITY of WETLANDS in the WOODWORTH STUDY AREA
Naomi E Detenbeck*, Colleen M Elonen, Debra L Taylor, U S Environmental Protection Agency, Mid-Continent Ecology Division, Duluth, MN

9:40 EFFECTS of WATER LEVEL CHANGES on PRAIRIE POTHOLE VEGETATION STRUCTURE and DIVERSITY in the WOODWORTH STUDY AREA, NORTH DAKOTA
Debra L Taylor* and Naomi E Detenbeck, U S Environmental Protection Agency, Mid-Continent Ecology Division, Duluth, MN

break

10:20 CHIRONOMIDAE (DIPTERA) of the WOODWORTH STUDY AREA, NORTH DAKOTA
Dale Wrubleski*, U S Environmental Protection Agency, Mid-Continent Ecology Division, Duluth, MN

10:40 HYDROLOGIC and SEDIMENTATION SIMULATION in the PRAIRIE POTHOLE REGION of NORTH DAKOTA
Baxter E Vieux*, Gary E Freeman, Erwan LeDimet, Sylvain Guinepain, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman and U S Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS

11:00 UPLAND VEGETATION at the WOODWORTH STUDY AREA
Mavis I Meyer*, U S Fish and Wildlife Service, Denver Federal Center, Denver, CO

11:20 TERRESTRIAL BIRD COMMUNITIES on the WOODWORTH STUDY AREA
Douglas H Johnson*, Northern Prairie Science Center, Jamestown

11:40 WATERFOWL STUDIES at the WOODWORTH STUDY AREA, STUTSMAN COUNTY, NORTH DAKOTA: 1965 - 1995
Kenneth F Higgins* and Robert O Woodward, South Dakota Cooperative Fish and Wildlife Research Unit, Brookings, SD, and Northern Prairie Science Center, Jamestown

lunch

1:30 WOODWORTH DATA and PLANNING for the PRAIRIE POTHOLE JOINT VENTURE
Ronald E Reynolds* and Michael A Johnson, U S Fish and Wildlife Service, Bismarck and North Dakota Game and Fish Department, Bismarck

1:50 EFFECTS of FIRE RETARDANT CHEMICALS and FIRE SUPPRESSANT FOAM on NORTH DAKOTA PRAIRIE VEGETATION
Diane L Larson* and Wesley E Newton, Northern Prairie Science Center, Jamestown

2:10 EFFECTS of TWO FIRE SUPPRESSANT FOAMS on BENTHIC INVERTEBRATES COLONIZING ARTIFICIAL SUBSTRATES in PORTABLE LIMNOCORRALS
Barry C Poulton*, National Biological Service, Midwest Science Center, Columbia, MO

2:30 EFFECTS of SILV-EX® on TERRESTRIAL WILDLIFE
Nimish B Vyas*, James W Spann, Elwood F Hill, Patuxent Environmental Science Center, Laurel, MD

2:50 LINKING RESEARCH with MANAGEMENT: A HISTORICAL PERSPECTIVE
Harvey K Nelson*, First Director, Northern Prairie Wildlife Research Center, U S Fish and Wildlife Service, Retired, Bloomington, MN

ECOLOGICAL STUDIES AT THE WOODWORTH STUDY AREA, NORTH DAKOTA: SESSION OVERVIEW AND OBJECTIVES

Ronald E. Kirby and Ned H. Euliss, Jr.*

National Biological Service, Northern Prairie Science Center, 8711 37th Street, Southeast, Jamestown, ND 58401

This special session of the Academy annual meeting was organized for three purposes. First, we thought it a good way to collect in one volume a "snapshot," if you will, of the current and past work conducted at the Woodworth Study Area (WSA) since 1965. Second, we thought it useful to emphasize the scope of the work at the WSA, particularly with regard to the range of ecological issues that have been evaluated and that are now under investigation. Finally, we thought this an excellent way to illustrate, by example, the positive aspects of long-term collaborative studies, especially in an era when perseverance to see long-term work through, and the budgets to maintain such studies, are in short supply.

The WSA was established as a result of the foresight of many persons in the U.S. Fish and Wildlife Service (FWS), but the development of the facility owes much to Ingalf G. Bue (1915-1963), who, on special assignment, traversed the Prairie Pothole Region in search of the perfect site for long-term research studies. The program at Woodworth has been administratively supported by the successive Directors of Northern Prairie Wildlife Research Center (now Northern Prairie Science Center): Harvey K. Nelson, W. Reid Goforth, Rey C. Stendell, Susan D. Haseltine, and Ronald E. Kirby. Many others, acknowledged in the individual papers to follow, provided day-to-day management of WSA and the imagination to make the concept flourish. We collaboratively managed the editorial duties for the submitted papers. Acknowledged herewith is the cooperation of everyone involved in preparation of this session, especially T.G. Hanson, who retyped manuscripts, and D.M. Mushet, who reworked numerous figures.

We have now entered a new era in wildlife research and management wherein the questions are more complex and the competition for funds to conduct studies is fierce. Simultaneously, the administration of the WSA has gone through a rearrangement of authorities and responsibilities. The land--always FWS property--and the buildings comprising the research facility--built with FWS funds through the Research Program--are now administered by different agencies, respectively the FWS and the National Biological Service (NBS). Making such dramatic change in long-term arrangements is difficult in any circumstance, but such is particularly difficult to engineer in structured bureaucracies. Nonetheless, through a formal agreement several years in the making, the FWS now retains its authority to manage the land with reference to the requirements inherent in its mission. Likewise, through this agreement the needs of the research program administered by Northern Prairie Science Center, now part of the NBS, are guaranteed. The site is thus perhaps unique within the Department of the Interior in that a land management and research program are meshed such that each is fully supportive of the other. Annual coordination meetings guarantee complementary priorities, and day-to-day management of the site is accomplished with great efficiency.

We believe that the work accomplished at the WSA to date is the best possible example of how management and research should be coordinated. We can think of no better outcome than this session encouraging others to develop similar arrangements to foster the needs of managers throughout the Great Plains and elsewhere for information on best management practices. The need is there. Federal, state, and private lands can ill-afford mismanagement; current availability of funds dictates that only the most efficient management be implemented. This session is thus in one sense a challenge to everyone that they "think big," and not be deterred by the complications of generating and then sustaining long-term, comprehensive studies. Only through such approaches can we determine what is our next best management decision in the face of oscillating wet-dry cycles, the extremes of climate, and the great changes agriculture has wrought in the environment of the northern Great Plains.

As will be obvious to those attending today and to those reading the proceedings, there are far more scientific products available from WSA studies than could be represented within the context of this special session. This will be especially obvious after examining the partial list of publications prepared by Johnson et al. (1) and Johnson (2). Thus, a complete overview was not possible. In addition, Nelson (3) discusses the various ways that scientific products from WSA have been integrated into a variety of natural resource management plans, both in the United States and internationally. Such integration has been a large part of the success of WSA studies. Thus, a full review of the ultimate impact of the research conducted at the WSA is also beyond the capabilities of this session. Although it was difficult to decide what to cover, we requested that presenters provide overviews of past work from representative disciplines and from the perspective of a more recent emphasis on broader ecological studies that require interdisciplinary approaches. New research presented herein, most of which is still in progress, reflects a similar theme. It is our desire that the examples set forth in the following papers provide not only information of direct scientific and management value, but also provide examples of the value of long-term studies in addressing changing priorities in natural resource science and management.

1. Johnson, D. H., Higgins, K. F. and Woodward, R. O. (1996) An introduction to the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

2. Johnson, D. H. (1996) Terrestrial bird communities on the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

3. Nelson, H. K. (1996) Linking research with management: a historical perspective. Proc. N.D. Acad. Sci. 50.

AN INTRODUCTION TO THE WOODWORTH STUDY AREA

Douglas H. Johnson[1]*, Kenneth F. Higgins[2]
and Robert O. Woodward[1]
*National Biological Service, [1]Northern Prairie Science Center,
8711 37th Street Southeast, Jamestown, ND 58401 and
[2]South Dakota Cooperative Fish and Wildlife Research Unit,
South Dakota State University, Wildlife and Fisheries
Sciences Department, Brookings, SD 57007*

The Woodworth Study Area (WSA) was purchased by the U.S. Fish and Wildlife Service (FWS) during the early 1960's as a waterfowl production area. Unlike most such areas, its primary purpose was not to provide waterfowl breeding habitat directly, but instead it was dedicated for use as a research area to develop information for better management of upland and wetland habitats. This article provides some history of the area and background information about biological monitoring and research that have been conducted on the WSA. Unless otherwise stated, information included is derived from (1) or unpublished data on file at the Northern Prairie Science Center (NPSC).

The driving concept behind the WSA was to have a sizable tract of land within the Missouri Coteau and close to the Northern Prairie Wildlife Research Center (now the Northern Prairie Science Center) in Jamestown, North Dakota (2). The Center itself was established in 1963 by the FWS to investigate migratory birds, with an emphasis on waterfowl, their life history, habitat needs, and potential for management. The Woodworth site was intended to provide a representative area for long-term research on habitat changes and responses by prairie waterfowl.

The study area is located in northwestern Stutsman County about 5 km east of the city of Woodworth. Elevation ranges from 561 to 594 MSL. Of the 1,231 ha, 1,073 are federally owned. The remainder consists of privately owned property whose owners allowed research to be conducted. Study area managers were Leo M. Kirsch (deceased) from 1964 to 1979, Kenneth F. Higgins during 1979-85, and J. Michael Callow from 1985 to 1989. Since 1989, the area has been managed from the Jamestown Center. The FWS is established on site and, in conjunction with the NPSC, coordinates management of the area to facilitate research.

GEOLOGY AND SOILS

The Missouri Coteau is a geologic formation that extends from east-central South Dakota through southwestern Saskatchewan. The Coteau is an area of morainic hills that rises 91-152 m above the adjacent Drift Plain. The Coteau consists primarily of dead-ice moraine left from the extensive glacial stagnation that followed advances of late Wisconsin glaciers. The drift has been aged at 9,000-13,000 years.

The study area itself includes two major landforms: hummocky stagnation moraine and stagnation outwash moraine (3). Hummocky stagnation moraine is rugged with an average elevation of more than 564 m MSL, and consists mainly of knobs and kettles. The dominant material is glacial till. Stagnation outwash moraines are extensive areas underlain by glaciofluvial material deposited in association with stagnating dead ice.

Parent materials of the soils were deposited by glacial ice. They are considered glacial till, a mixture of sand, silt, clay, pebbles, and stones, without sorting by size. The major soil association is Buse-Barnes (4, 5). Svea, Renshaw, Fordville, Sioux, Parnell, Colvin, and Tetonka soils also occur, the latter three mainly in wetland basins.

CLIMATE

The climate of the area is continental, characterized by a high evapo-transpiration ratio, cold winters, and warm summers. Average relative humidity is 68%. Precipitation records were taken in the city of Woodworth during 1961-66 and at the study area subsequently. Mean precipitation during 1964-81 was 41 cm; the long-term average for the general area was 44 cm. Precipitation in most years is greatest during summer.

Mean temperature for the area is 4°C, with January being the coldest month and July the warmest. The frost-free period averages 120 days, roughly between 20 May and 15 September. Prevailing winds are from the northwest, with an average speed of 16 km/h. Winds are typically strongest during the afternoon and calmest at night.

LAND-USE HISTORY

The Woodworth area was settled by Europeans about 1900 (6). Prior to acquisition by the FWS, fields composing the study area were mostly used for grazing by cattle, sheep, and horses. About a fourth of the area had been cultivated, but some of it for only short periods.

Since acquisition, most of the study area, especially native prairie, was managed primarily by prescribed burning, grazing, and leaving idle. Areas that had been cultivated were planted, either to native grasses or to a mixture of tame grasses and legumes that were recommended for waterfowl nesting habitat. Reseeded areas were managed by fire, scarification, and to a limited extent, fertilization. Little management of wetlands has taken place, although in recent years several wetlands that had been drained have been restored by the FWS.

VEGETATION

The native vegetation on the WSA is xeric mixed-grass prairie, which has been invaded by woody species--especially wolfberry (*Symphoricarpos occidentalis*), silverberry (*Elaeagnus commutata*), chokecherry (*Prunus virginiana*), and Woods rose (*Rosa woodsii*)--and introduced grasses--notably Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and quackgrass (*Agropyron repens*). Vegetation on the study area is discussed in more detail by Meyer (7).

WETLANDS

The study area contains 548 wetland basins. The distribution by class for 344 basins that contained water during mid-May surveys is presented in Table 1, along with the total area for each class. Wetlands were either fresh (typically <40 - 500 mmhos/cm^3) or slightly brackish (typically 500 - 2,000 mmhos/cm^3), as defined by Stewart and Kantrud (8).

Table 1. Distribution of wetlands on Woodworth Study Area according to class.

Wetland class	Number of basins	Total area (ha)
Ephemeral	12	1
Ephemeral-tilled	2	1
Temporary	43	8
Temporary-tilled	2	1
Seasonal	229	170
Seasonal-tilled	4	3
Semipermanent	43	250
Permanent	1	53
Dugout or dam	8	46
Total	344	533

LONG-TERM STUDIES AND MONITORING

A number of habitat and wildlife surveys have been conducted for long periods on the WSA. All wetlands were surveyed, usually five times each year, once in each of the following periods: 1-15 May, 1-15 June, 16-30 June, 1-15 July, and 1-15 August. Basins were classified as wet if they were at least 5% inundated and the water was 2.5 cm or more deep. Wetlands were classified (8) annually during 1963-73 and in 1975, 1980, 1983, and 1988.

Upland vegetation was monitored with a series of transects, and first flowering dates were recorded for many species (9). Each transect consisted of a number of Daubenmire quadrats. Twelve transects were established on the area in 1966, but two were discontinued after four years. During the first few years, only the end points of the transects were permanently marked, and individual quadrats were located by equidistant pacing. In 1973, all quadrats were marked. Each transect included 7-14 square quadrats, each 1.5 m on a side. Woodworth Field Station staff and volunteers surveyed the transects once each year during 1966-89, in summer or later. They recorded the plant species composition in each quadrat according to Daubenmire coverage classes. In addition, environmental variates were recorded for each quadrat, including soil type, moisture regime (upland, lowland, wet meadow, or wetland), slope, and aspect. Kirsch and Kruse (10) reported preliminary results based on four of the transects. Johnson (11) analyzed data for 1966-82, focusing on 15 of the most common plant species, of the 228 identified.

Photo stations were placed in 33 areas that represented the three major cover types on the study area: native grassland, seeded native grassland, and seeded dense nesting cover. Photos were taken during 1970-89 once in mid April or May before new plant growth began to dominate residual vegetation and again in August after the growing season. The photos visually depicted changes in vegetation structure and composition resulting from land-use treatments such as grazing, burning, and other types of habitat manipulation.

Breeding waterfowl were censused annually during 1965-89. Numerous counts were made during the earlier years, but beginning in 1972, two were considered adequate. These were made between 10 April and 10 July each year, but counts taken near 1 May and near 1 June ultimately were used for population determination. Censuses were made while walking or driving around the periphery of wetland basins. Total number of duck pairs ranged from 236 to 692, and averaged 492 during 1965-89. Averages by species are presented in Table 2.

Table 2. Average number of indicated breeding pairs (1965-89), nests (1966-81), and broods (1965-81) of ducks on Woodworth Study Area.

Species	Pairs	Nests	Broods
Mallard (*Anas platyrhynchos*)	52	26	13
Gadwall (*A. strepera*)	64	43	21
American Wigeon (*A. americana*)	10	4	3
Green-winged Teal (*A. crecca*)	8	4	3
Blue-winged Teal (*A. discors*)	211	133	74
Northern Shoveler (*A. clypeata*)	30	12	7
Northern Pintail (*A. acuta*)	27	15	7
Redhead (*Aythya americana*)	26	NA[1]	4
Canvasback (*A. valisineria*)	10	NA[1]	3
Lesser Scaup (*A. affinis*)	30	3[1]	4
Ruddy Duck (*Oxyura jamaicensis*)	25	NA[1]	8

[1]Redheads, canvasbacks, ruddy ducks, and some lesser scaup nest over water, where nest searches were not conducted.

Nests of waterfowl were searched for and monitored in most years. Three or four searches were made each year, usually beginning the first week in May and concluding by mid July. A cable-chain device, towed between two jeeps, was developed at the Station (12) and used to find nests by flushing attending females. (The device has since become a standard technique for waterfowl nesting studies.) Information recorded at each nest included number of eggs, stage of incubation, and habitat features of the nest site and surrounding field. Nests were revisited periodically to monitor fates of the clutches. During 1966-81, 3,832 duck nests were found, ranging from 65 to 424 per year (Table 2).

Broods of waterfowl were also counted, although the secretiveness of ducklings resulted in very minimal estimates of the total number (Table 2). Two brood counts were made each year, one in early July and one in early August. Counts involved visiting each wetland on the study area, and wading through wetlands to flush the birds. Species, age class, and number of ducklings were recorded.

Terrestrial bird communities were censused annually during 1972-95. Censuses were conducted on as many as 10 plots, but six plots were surveyed in all years. Census plots ranged in size from 4.86 to 10.12 ha. Each was visited about eight times each year, and locations of birds were recorded on field maps. After all surveys were done, territories were plotted and the number of pairs of each species was estimated. Details of these censuses are reported separately (13).

In addition, surveys were made each year of dancing grounds of sharp-tailed grouse (*Tympanuchus phasianellus*). Incidental observations were made of other species as well. For migratory birds, dates of first sighting each spring were recorded.

Beyond the monitoring programs described, numerous scientists conducted shorter-term studies based at Woodworth. Those done by NPSC staff are listed in Appendix 1. Table 3 mentions those performed by visiting scientists.

Table 3. Short-term biological studies conducted by non-Northern Prairie Science Center personnel on the Woodworth Study Area.

Investigator	Study
Oetting, Robert B.	Ph.D. (1970) Waterfowl nesting on Interstate Highway right-of-way in North Dakota. North Dakota State University, Fargo.
Howe, Marshall A.	Ph.D. (1972) Pair bond formation and maintenance in Wilson's Phalarope (*Phalaropus tricolor*). University of Minnesota, St. Paul.
Strait, Laurence E.	M.S. (1973) Population dynamics of a white pelican population, Chase Lake NWR, North Dakota. Michigan Technological University, Houghton.
Johnson, Robert F.	M.S. (1976) Mortality factors affecting a white pelican population, Chase Lake NWR, North Dakota. Michigan Technological University, Houghton.
Johnson, Michael A.	M.S. (1977) Productivity of hand-reared Canada geese released in North Dakota. University of Minnesota, St. Paul.
Lingle, Gary L.	M.S. (1977) Food habits and sexing-aging criteria of the white pelican at Chase Lake National Wildlife Refuge, North Dakota. Michigan Technological University, Houghton.
Rudzinski, Don	M.S. (1980) Behavioral interaction of penned red and Arctic foxes. Pennsylvania State University, University Park.
Ryan, Mark	Ph.D. (1982) Marbled godwit habitat selection in the Northern Prairie Region. Iowa State University, Ames.
Renken, Rochelle	M.S. (1983) Breeding communities and bird habitat associations on North Dakota waterfowl production areas of three habitat types. Iowa State University, Ames.
Arnold, Todd	M.S. (1986) The ecology of prairie mink during the waterfowl breeding season. University of Missouri, Columbia.
Eagle, Thomas C.	Ph.D. (1989) Movement patterns of mink in the Prairie Pothole Region of North Dakota. University of Minnesota, St. Paul.
White, P. J.	M.S. (1990) The pathological responses of red foxes to capture in unpadded foothold traps and box traps as revealed by physiological telemetry and biochemical assays. University of Minnesota, St. Paul.
Kreeger, Terry J. Monson, Daniel Kuechle, Valerian B. Seal, Ulysses S. Tester, John R.	(1989) Monitoring heart rate and body temperature in red foxes (*Vulpes vulpes*). Can. J. Zool. 67,2455-2458.
White, P. J. Kreeger, Terry J. Tester, John R. Seal, Ulysses S.	(1989) Anal sac secretions deposited with feces by captive red foxes (*Vulpes vulpes*). J. Mammal. 70,814-816. (1990) Pathological responses of red foxes to foothold traps. J. Wildl. Manage. 54,147-160. (1991) Pathological responses of red foxes to capture in box traps. J. Wildl. Manage. 55,75-80.

Acknowledgment--We are grateful to Robert A. Gleason for his help in compiling the publication list for Appendix 1.

---

1. Higgins, K. F., Kirsch, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl production on the Woodworth Station in south-central North Dakota, 1965-1981. U.S. Fish Wildl. Serv. Resour. Publ. 180.

2. Nelson, H. K. (1992) *in* (1), p. iii.

3. Winters, H. A. (1963) Geology and ground water resources of Stutsman County, North Dakota. Part I. Geology. N.D. State Water Commiss. Bull. 41.

4. Omodt, H. W., Johnsgard, G. A., Patterson, D. D and Olson, O. P. (1968) The major soils of North Dakota. N.D. Agric. Exper. Sta. Bull. 472.

5. Patterson, D. D., Johnsgard, G. A., Sweeney, M. D. and Omodt, H. W. (1968) Soil survey report, county general soils maps, North Dakota. N.D. Agric. Exper. Sta. Bull. 473.

6. Bayha, K. D. History of the Woodworth Study Area with emphasis on land use. North. Prairie Sci. Center, Jamestown, ND. (Unpubl. Rept.)

7. Meyer, M. I. (1996) Upland Vegetation at the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

8. Stewart, R. E. and Kantrud, H. A. (1971) Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish Wildl. Serv. Resour. Publ. 92.

9. Callow, J. M., Kantrud, H. A. and Higgins, K. F. (1992) First flowering dates and flowering periods of prairie plants at Woodworth, North Dakota. Prairie Nat. 24,57-64.

10. Kirsch, L. M. and Kruse, A. D. (1973) Prairie fires and wildlife. Proc. Annu. Tall Timbers Fire Ecol. Conf. 12,289-303.

11. Johnson, D. H. Relations of selected prairie plants with environmental attributes on the Woodworth Study Area, North Dakota. North. Prairie Sci. Center, Jamestown, ND. (Unpubl. Rept.)

12. Higgins, K. F., Kirsch, L. M. and Ball, I. J., Jr. (1969) A cable-chain device for locating duck nests. J. Wildl. Manage. 33,1009-1011.

13. Johnson, D. H. (1996) Terrestrial bird communities on the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

Appendix 1. Partial list of publications emanating from studies conducted, mostly by Northern Prairie Science Center scientists, that involved the Woodworth Study Area. Omitted are breeding bird census results listed in the Appendix of (13).

Arnold, T. W. and Higgins, K. F. (1986) Effects of shrub coverages on birds of North Dakota mixed-grass prairies. Can. Field-Nat. 100,10-14.

Callow, J. M., Kantrud, H. A. and Higgins, K. F. (1992) First flowering dates and flowering periods of prairie plants at Woodworth, North Dakota. Prairie Nat. 24,57-64.

Dane, C. W. and Pearson, G. L. (1971) Effect of spring storm on waterfowl mortality and breeding activity. Pages 258-267 *in* A. O. Haugen, ed. Proc. Snow and Ice in Relation to Wildlife and Recreation Symp. Iowa Coop. Wildl. Res. Unit and Iowa State Univ., Ames.

Doty, H. A. (1974) Wood ducks in North Dakota. Prairie Nat. 6,17-21.

Duebbert, H. F. (1983) Seeded grasslands for wildlife habitat in the prairie pothole region. Pages 27-28 *in* Management of public lands in the Northern Great Plains. Wildl. Soc., N.D. Game Fish Dept., and U.S. Fish Wildl. Serv.

Duebbert, H. F. (1984) Seeded grasslands for wildlife benefits. Pages 43B-45B in F. R. Henderson, ed. Guidelines for increasing wildlife on farms and ranches. Kansas State Univ., Manhattan.

Duebbert, H. F. (1987) Planted grasslands for wildlife habitat in the prairie pothole region. Proc. N.D. Acad. Sci. 41,41.

Duebbert, H. F., Jacobson, E. T., Higgins, K. F. and Podol, E. B. (1981) Establishment of seeded grasslands for wildlife habitat in the Prairie Pothole Region. U.S. Fish Wildl. Serv. Spec. Sci. Rep. 234.

Duebbert, H. F. and Lokemoen, J. T. (1977) Upland nesting of American bitterns, marsh hawks, and short-eared owls. Prairie Nat. 9,33-40.

Eagle, T. C., Choromanski-Norris, J. and Kuechle, V. B. (1984) Implanting radio transmitters in mink and Franklin's ground squirrels. Wildl. Soc. Bull. 12,180-184.

Eaglè, T. C. and Sargeant, A. B. (1980) Learning about mink. N.D. Outdoors 43,16-18.

Eagle, T. C. and Sargeant, A. B. (1985) Use of den excavations, decoys, and barrier tunnels to capture mink. J. Wildl. Manage. 49,40-42.

Grue, C. E., DeWeese, L. R., Mineau, P., Swanson, G. A., Foster, J. R., Arnold P. M., Huckins, J. N., Sheehan, P. J. Marshall, W. K. and Ludden, A. P. (1986) Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: an evaluation of research needs and approaches. Trans. N. Am. Wildl. and Nat. Resour. Conf. 51,357-383.

Grue, C. E., Tome, M. W., Swanson, G. A., Borthwick, S. M. and DeWeese, L. R. (1988) Agricultural chemicals and the quality of prairie-pothole wetlands for adult and juvenile waterfowl - what are the concerns? U.S. Fish Wildl. Serv., Biol. Rept. 88.

Grue, C. E., Tome, M. W., Messmer, T. A., Henry, D. B., Swanson, G. A. and DeWeese, L. R. (1989) Agricultural chemicals and prairie pothole wetlands: Meeting the needs of the resource and the farmer -- U.S. perspective. Trans. N. Am. Wildl. Nat. Resour. Conf. 54,43-58.

Higgins, K. F. (1971) Cowbird parasitism of an upland plover nest. Prairie Nat. 3,79.

Higgins, K. F. (1974) Prolonged incubation behavior by a marbled godwit. Auk 91,167.

Higgins, K. F. (1975) Shorebird and game bird nests in North Dakota croplands. Wildl. Soc. Bull. 3,176-179.

Higgins, K. F. (1977) Duck nesting in intensively farmed areas of North Dakota. J. Wildl. Manage. 41,232-242.

Higgins, K. F. (1982) Principal flora and wildlife use of a 35-40 year old gravel pit in North Dakota. Pages 159-161 *in* W. D. Svedarsky and R. D. Crawford, eds. Proc. Wildlife Values of Gravel Pits Symp. Univ. of Minnesota, Crookston.

Higgins, K. F. (1984) Lightning fires in North Dakota grasslands and in pine-savanna lands of South Dakota and Montana. J. Range Manage. 37,100-103.

Appendix 1. **(continued)**

Higgins, K. F. (1986) A comparison of burn season effects on nesting birds in North Dakota mixed-grass prairie. Prairie Nat. 18,219-228.

Higgins, K. F. (1986) Further evaluation of duck nesting on small man-made islands in North Dakota. Wildl. Soc. Bull. 14,155-157.

Higgins, K. F. (1986) Waterfowl nesting on an earth-filled cement culvert. Prairie Nat. 18,115-116.

Higgins, K. F., Arnold, T. W. and Barta, R. M. (1984) Breeding bird community colonization of sown stands of native grasses in North Dakota. Prairie Nat. 16,177-182.

Higgins, K. F. and Barker, W. T. (1982) Changes in vegetation structure in seeded nesting cover in the Prairie Pothole Region. U.S. Fish Wildl. Serv. Spec. Sci. Rep.--Wildl. 242.

Higgins, K. F., Duebbert, H. F. and Jacobson, E. T. (1982) Successful establishment of stands of cool-season native grasses (North Dakota). Restorat. and Manage. Notes 1,12.

Higgins, K. F., Duebbert, H. F. and Oetting, R. B. (1969) Nesting of the upland plover on the Missouri Coteau. Prairie Nat. 1,45-48.

Higgins, K. F., Fellows, D. P., Callow, J. M., Kruse, A. D. and Piehl, J. L. (1989) Annotated bibliography of fire literature relative to northern grasslands in south-central Canada and north-central United States. U.S. Fish Wildl. Serv., and Coop. Ext. Serv., S.D. State Univ., U.S. Dept. of Agric. EC 762.

Higgins, K. F. and Kirsch, L. M. (1975) Some aspects of the breeding biology of the upland sandpiper in North Dakota. Wilson Bull. 87,96-102.

Higgins, K. F., Kirsch, L. M. and Ball, I. J., Jr. (1969) A cable-chain device for locating duck nests. J. Wildl. Manage. 33,1009-1011.

Higgins, K. F., Kirsch, L. M. and Callow, J. M. (1980) Spring arrival of birds at Woodworth, North Dakota. Prairie Nat. 12,89-91.

Higgins, K. F., Kirsch, L. M., Duebbert, H. F., Klett, A. T., Lokemoen, J. T., Miller, H. W. and Kruse, A. D. (1977) Construction and operation of cable-chain drag for nest searches. U.S. Fish Wildl. Serv. Wildl. Leafl. 512.

Higgins, K. F., Kirsch, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl production on the Woodworth Station in south-central North Dakota, 1965-1981. U.S. Fish Wildl. Serv. Resour. Publ. 180.

Higgins, K. F., Kirsch, L. M., Ryan, M. R. and Renken, R. B. (1979) Some ecological aspects of marbled godwits and willets in North Dakota. Prairie Nat. 11,115-118.

Higgins, K. F., Kruse, A. D. and Piehl, J. L. (1989) Effect of fire in the Northern Great Plains. U.S. Fish Wildl. Serv., and Coop. Ext. Serv., S.D. State Univ., U.S. Dept. of Agric. EC 761.

Higgins, K. F., Kruse, A. D. and Piehl, J. L. (1989) Prescribed burning guidelines in the Northern Great Plains. U.S. Fish Wildl. Serv., and Coop. Ext. Serv., S.D. State Univ., U.S. Dept. of Agric. EC 760.

Johnson, D. H. (1976) Effects of grassland burning on breeding birds--preliminary report. Proc. N.D. Acad. Sci. 30,24.

Johnson, R. F., Jr. and Kirsch, L. M. (1977) Egg movement by a female gadwall between nest bowls. Wilson Bull. 89,331-332.

Johnson, R. F., Jr., Woodward, R. 0. and Kirsch, L. M. (1978) Waterfowl nesting on small man-made islands in prairie wetlands. Wildl. Soc. Bull. 6,240-243.

Kantrud, H. A. and Higgins, K. F. (1992) Nest and nest site characterisitcs of some ground-nesting, non-passerine birds of northern grasslands. Prairie Nat. 24,67-84.

Kirsch, L. M. (1969) Waterfowl production in relation to grazing. J. Wildl. Manage. 33,821-828.

Kirsch, L. M., Duebbert, H. F. and Kruse, A. D. (1978) Grazing and haying effects on habitats of upland nesting birds. Trans. N. Am. Wildl. Nat. Resour. Conf. 43,486-497.

Appendix 1. (continued)

Kirsch, L. M. and Higgins, K. F. (1976) Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4,16-20.

Kirsch, L. M. and Kruse, A. D. (1973) Prairie fires and wildlife. Proc. 1972 Annu. Tall Timbers Fire Ecol. Conf. 12,289-303.

Klett, A. T., Duebbert, H. F., Faanes, C. A. and Higgins, K. F. (1986) Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U.S. Fish Wildl. Serv. Resour. Publ. 158.

Klett, A. T. and Kirsch, L. M. (1976) Diurnal use of small wetlands by ducks. J. Wildl. Manage. 40,351-353.

Lee, F. B., Schroeder, C. H., Kuck, T. L., Schoonover, L. J., Johnson, M. A., Nelson, H. K. and Beauduy, C. A. (1984) Rearing and restoring giant Canada geese in the Dakotas. N.D. Game Fish Dept., Bismarck.

Lokoemon, J. T., Duebbert, H. F. and Sharp, D. E. (1990) Homing and reproductive habits of mallards, gadwalls, and blue-winged teal. Wildl. Monogr. 106.

Meyer, M. I. (1985) Classification of native vegetation at the Woodworth Station, North Dakota. Prairie Nat. 17,167-175.

Meyer, M. I. (1987) Planting grasslands for wildlife habitat. U.S. Fish Wildl. Serv., N. Prairie Wildl. Res. Ctr., Jamestown, ND.

Preston, E. M. (1975) Home range defense in the red fox (*Vulpes vulpes* L.). J. Mammal. 56,645-652.

Renken, R. B. and Dinsmore, J. J. (1982) A Henslow's sparrow in North Dakota. Prairie Nat. 14,98.

Renken, R. B. and Dinsmore, J. J. (1987) Nongame bird communities on managed grasslands in North Dakota. Can. Field-Nat. 101,551-557.

Rudzinski, D. R., Graves, H. B., Sargeant, A. B. and Storm, G. L. (1982) Behavioral interactions of penned red and arctic foxes. J. Wildl. Manage. 46,877-884.

Sargeant, A. B. and Eberhardt, L. E. (1975) Death feigning by ducks in response to predation by red foxes (*Vulpes vulpes*). Am. Midl. Nat. 94,108-119.

Sargeant, A. B.; Sovada, M. A. and Greenwood, R. J. (In Press) Collecting and interpreting evidence of predation of duck clutches. Ducks Unlimited, Inc.

IMPACT OF AGRICULTURAL LAND-USE ON PRAIRIE WETLAND ECOSYSTEMS: EXPERIMENTAL DESIGN AND OVERVIEW

Robert A. Gleason* and Ned H. Euliss, Jr.
National Biological Service
Northern Prairie Science Center
8711 37th Street Southeast
Jamestown, ND 58401

Most wetlands in the Prairie Pothole Region (PPR) are on private lands and are embedded within an agricultural landscape (1, 2). The influence of agricultural land-use practices on wetland ecosystems is largely unknown but potential impacts include the direct and indirect application of agrichemicals (2, 3) and increased sedimentation. Cultivation of wetland basins and associated watersheds also facilitates transport of chemicals adsorbed on soil particles into wetlands. Intuitively, increased sedimentation leads to the ultimate loss of wetland habitat as basins are filled with allochthonous materials and increased turbidity and covering of substrates decreases primary production. Although a few studies in the PPR have examined the impact of agricultural activities on wetland sedimentation rates (4, 5), the impacts of increased sedimentation on water quality, primary productivity, aquatic invertebrates, and bird use are poorly understood.

To address this information need, a 2-year field study was initiated in 1993 to examine the impacts of common agricultural land-use practices on prairie wetlands and to assess potential impacts on wetland biota in the PPR. This research was a collaborative effort involving the National Biological Service's Northern Prairie Science Center (NPSC), the U.S. Environmental Protection Agency's Mid-Continent Ecology Division (EPAMED), the U.S. Army Corps of Engineers Waterways Experiment Station (USAWES), the National Research Council (NRC), the University of Minnesota's Cooperative Fish and Wildlife Research Unit (MCFWRU), and Humboldt State University. The objectives of this collaborative work were broad, including a determination of the effects of sedimentation on water quality, vegetation, aquatic invertebrates, waterfowl use, and aquatic food webs. Additionally, the work was designed to evaluate management tools used to mitigate sedimentation impacts on wetlands. NPSC monitored macroinvertebrate communities and waterfowl use, and EPAMED monitored water quality and plant and algal communities (6, 7); sedimentation data were collected and processed jointly by NPSC and the EPAMED. Data collected jointly on weather, sedimentation, water balance, and basin morphometry by NPSC and EPAMED were used to develop a hydrologic sediment model for the PPR by the USAWES (8). In addition, investigations on secondary productivity and sediment impacts on food webs was initiated by the NRC with support from EPAMED (9). Lastly, *in vitro* experiments on the effects of sediment and agrichemicals on aquatic invertebrates was conducted by MCFWRU. In this paper, we provide the overall framework for this larger interdisciplinary effort, including the experimental design, methods, and evaluation, and provide an overview of the findings on sedimentation, waterfowl use, and macroinvertebrates. Funding for this study was provided by EPAMED and NPSC; access to study sites was provided by the U.S. Fish and Wildlife Service (USFWS).

EXPERIMENTAL DESIGN

The experimental design consisted of assigning five wetlands to the following replicate land-use practices: 1) idled native grassland, 2) idled non-native grasslands (i.e., lands similar to Conservation Reserve Program lands; CRP), 3) summer-fallowed agricultural lands, and 4) summer-fallowed agricultural lands with wetlands protected by vegetative bufferstrips. All 20 study wetlands were on USFWS Waterfowl Production Areas (WPA's) located on the eastern edge of the Missouri Coteau, near Woodworth, North Dakota. Sixteen wetlands were located on the Woodworth Study Area (WSA), and the remaining 4 wetlands were located on WPA's within 10 km of Woodworth.

The 4 watershed treatments we selected for evaluation represent common land-use practices in the PPR. Summer fallow, bufferstrip, and CRP treatment wetlands had prior-cultivated cropland land-use history. Summer fallow is a common crop rotation practice in the PPR that consists of idling the land during the growing season, except for periodic cultivation to control weeds. Summer fallow fields have no protective covering and are highly vulnerable to soil loss. Our bufferstrip treatment was similar to summer fallow except that a standard U.S. Soil Conservation Service 7.62 m bufferstrip (10) of grassy vegetation was left around the perimeter of the wetland to reduce erosion of upland soil into wetland basins. Our CRP treatment was representative of lands currently enrolled in the CRP program in North Dakota except that they were located on WPA's and were managed by the USFWS as dense nesting cover for waterfowl. Our native prairie treatment had no prior tillage history and was still dominated by native mixed-grass prairie vegetation although some exotic plant species were present.

We selected seasonal wetlands (11) for study because they are commonly cultivated (12) and they are the most abundant class of wetlands in the PPR (1, 13, 14). We selected a population of potential wetland replicates that were similar with respect to size, soils, historically similar wetland class (1970-88), and land-use practices (1950's-present) based on an extensive database maintained by NPSC on the WSA (15). Wetlands also were visually inspected to ensure they had generally similar vegetation and had non-integrated watersheds of similar size and slope. Population size of wetlands available for random assignment to land-use treatments was constrained by our selection criteria and compatibility of certain experimental land-use treatments (i.e., those requiring tillage) with management goals of the USFWS. Although a completely random assignment of study wetlands to treatments was not possible, we believe the sites selected were representative of area wetlands given our logistical constraints. All land-use treatments requiring tillage were located on the WSA, an area set aside for manipulative research projects since the mid-1960s. All wetlands in our sample had similar land-use histories within treatment and were classified as seasonals (11) 75% or more of the time from 1970-1988 (Table 1). Wetlands ranged in size from 0.09 to 0.47 ha with shoreline lengths of 93 to 365 m and had watersheds from 0.5 to 1.8 ha (Table 1). Soils were of a Barnes-Buse-Parnell complex (Table 1) with slopes of 0 to 35%, and soil capability classification ranges of IIIe-VIIIe, indicating the main hazard was from soil erosion when nonvegetated (16). Major soils such as Barnes occurred on side and foot slopes and Buse soils on summits and shoulder slopes. Parnell was the major wetland soil. Although we attempted to select wetlands with non-integrated watersheds, surface outflow and/or inflow was observed in 8 wetlands during unusually high water levels in 1993 and 1994 (Table 1).

In 1993, we delineated wetland basins and watersheds. Wetland basins were delineated based on zonation by hydrophytic vegetation and consideration of change in soil type whereas watershed boundaries were delineated by topography; watersheds were defined as the catchment area that contributed surface runoff to a particular wetland.

Tilling of watersheds began in 1993 and continued as needed (usually monthly) during the 1993 and 1994 field season. Because only the watersheds were tilled, our treatments were not entirely representative of an agricultural landscape where wetlands are located in large tilled fields devoid of perennial cover. Also because of the proximate nature of study wetlands to nesting cover and other managed wildlife habitat, observations of wildlife use were likely inflated relative to a more representative agricultural landscape.

Elevations were determined in each wetland basin along five random transects that radiated from the center of the wetland (defined as the deepest point in the wetland basin) using a laser level. These elevations were used to define each wetland's basin and watershed morphometry and the mid-elevation of the wet-meadow and shallow emergent vegetative zones. A nest of 4 different sediment trap designs was installed along each transect (hereinafter called sediment transects) at the mid-elevation of the wet-meadow and shallow emergent vegetative zone, and the mid-elevation between the shallow emergent zone and center of the wetland. Traps installed included cylinder sediment traps (17, 18), filter sediment traps (19), wind deposited sediment traps designed for this study, and feldspar horizon markers (20). Cylinder sediment traps were used to estimate total downward flux of allochthonous and autochthonous sediment particles, feldspar horizon markers and filter sediment traps provided measures of net-sediment input, and wind sediment traps measured wind deposited sediment. Surface runoff was measured using modified surface flow traps (21) in areas of concentrated flow at the wetland edge and watershed boundary.

To reduce disturbance of substrates along sediment transects, invertebrate and vegetative monitoring was conducted on transects that radiated from the center of the wetland and bisected the angle between the sedimentation transects. Invertebrates were sampled on the left side (facing the wetland center) of the transect and vegetation work was conducted on the right. Other instrumentation installed include staff gauges which were installed in the center of each wetland and rain gauges which were installed in each watershed. In 1994, weather stations were also installed on all 4 WPA's. Aerial photographs of each wetland were geo-referenced using geographic positioning system equipment in 1994. Variables monitored for collaborative purposes are listed in Table 2.

PRELIMINARY RESULTS AND CONCLUSIONS

Preliminary results indicate that soil loss was greatest in summer fallow, followed by bufferstrip, CRP, and native prairie. Sedimentation rates estimated from cylinder sediment traps in 1993 indicated that in all wetland zones, summer fallow had significantly greater ($P<0.05$) total sedimentation rates than native prairie, CRP, and bufferstrip wetlands. Further, the inorganic fraction of sediment entering wetlands was significantly greater ($P<0.05$) in summer fallow than in the other land-use treatments. A complete synthesis on the interactions of response variables with explanatory variables is not yet available but will be provided in subsequent reports. However, it was clear that overall invertebrate density and biomass was similar among all land-use treatments both years. Analysis of individual invertebrate taxa indicated that most differences observed were probably related more to dynamic hydrologic cycles rather than to land-use treatment. Differences in waterfowl use among treatments also were not detected. Although some impacts from increased sedimentation were observed, monitoring of cumulative impacts from periods exceeding 2 years may be required to fully document impacts on invertebrates and birds. The dynamic hydrology of prairie wetlands has a profound influence on the ecology of waterfowl and other biota. For example, the first year of this study was one of the driest years recorded in this past century and the second year was one of the wettest. Studies that capture the temporal periodicity of drought cycles (i.e., 10-30 years) will be required to elucidate all but the most catastrophic impacts. Regardless, our study identified significant transport of sediments from uplands into prairie wetlands with the greatest impacts observed in wetlands surrounded by summer fallow followed by bufferstrip wetlands, non-native grassland (CRP) wetlands, and relatively pristine native prairie wetlands, respectively. However, this is based on sediment data collected during the first year of tillage when much organic debris was still present in tilled soils to retard erosion. Although sedimentation data for 1994 are not yet available, field observations suggest that bufferstrip wetlands performed poorly during the second year of our study, perhaps as poorly as we observed on wetlands in summer fallow in 1993. Reasons for this reduced performance were likely related to the oxidation and loss of binding organic debris in tilled soils and the fact that unusually high water levels in 1994 flooded bufferstrips, thus reducing their effective width.

Table 1. Physical characteristics of study wetlands on U.S. Fish and Wildlife Service Waterfowl Production Areas (WPA's), Stutsman County, North Dakota, selected for the sedimentation study, 1993-1994.

Land-use treatment	Wetland number	WPA	Wetland area (ha)	Shore-length (m)	%[a] wetland class	1993[b] $\bar{x}$ water level (cm)	1994[c] $\bar{x}$ water level (cm)	Upland[d] soils	Historic[e] land-use TI	SF	CR	BU	HA	GR	Outlet[f]	Inlet[g]
Native prairie	0232	Woodworth	0.20	159	100	32.2	112.5	Barnes-Buse				x		x		
	0717	Woodworth	0.17	203	100	49.4	107.8	Barnes-Buse				x	x	x		
	0718	Woodworth	0.16	203	100	41.2	100.6	Barnes-Buse				x	x	x		
	1615	Woodworth	0.24	244	88	37.7	99.0	Barnes-Buse				x		x		
	2224	Woodworth	0.14	197	88	54.2	90.4	Barnes-Buse				x			x	
CRP	0724	Woodworth	0.11	149	75	41.0	40.4	Barnes-Buse	x		x	x	x	x	x	x
	13E1	Strong	0.20	224	NA	24.5	77.2	Barnes-Buse	x	x	x		x	x	x	
	13E2	Strong	0.13	214	NA	9.0	48.2	Barnes-Buse	x	x	x		x	x	x	
	14A1	Sunday Lake	0.12	93	NA	12.0	40.0	Barnes-Svea-Buse	x	x	x		x	x		
	2401	Barnes Lake	0.10	150	NA	26.1	23.6	Barnes-Svea-Buse	x	x	x		x	x		
Bufferstrip	0118	Woodworth	0.25	264	88	42.2	66.7	Barnes-Buse	x	x	x				x	
	0228	Woodworth	0.14	187	100	15.9	63.9	Barnes-Buse	x	x	x			x		
	0229	Woodworth	0.13	199	86	18.7	47.1	Barnes-Buse	x	x	x			x		
	0230	Woodworth	0.21	226	100	27.6	92.0	Barnes-Buse	x	x	x			x		
	0732	Woodworth	0.09	180	88	31.2	68.9	Barnes-Buse	x		x	x	x	x	x	
Summer fallow	0317	Woodworth	0.16	209	100	54.0	57.7	Barnes-Svea-Buse	x	x	x	x	x	x	x	x
	0612	Woodworth	0.19	219	88	47.2	90.7	Barnes-Buse	x	x	x	x	x		x	
	0615	Woodworth	0.13	194	100	54.1	94.2	Barnes-Buse	x	x	x	x	x			x
	0623	Woodworth	0.47	365	100	71.0	130.2	Barnes-Buse	x	x	x	x	x			
	0706	Woodworth	0.23	274	100	44.5	105.2	Barnes-Buse	x	x	x	x	x			

[a]% of time wetland was classified as seasonal 1970-1988 (n=8), NA=data not available.
[b]Average water depth May-July 1993 (n=22-35).
[c]Average water depth April-August 1994 (n=38).
[d]Soil series (Stutsman County Soil Survey, North Dakota)
[e]Historical land-use practices: tilled (TI), summer fallow (SF), cropland (CR), burning (BU), haying (HA), grazing (GR).
[f]Presence of an overland water outlet during high water levels 1993-1994.
[g]Presence of an overland water inlet during high water levels 1993-1994.

Table 2. Summary of measurement endpoints collected during the sedimentation study, May-July 1993 and April-August 1994.

Hydrology and climatology	Macrophytes
Water level	Vegetation biomass
Precipitation	Vegetation composition
Relative humidity	Cover
Soil moisture	Density
Wind speed and direction	Species diversity
Solar radiation	Periphyton, Metaphyton, and Benthic Algae
Sediment	Biomass
Sedimentation rates (mass/area/time)	Macroinvertebrates
Sediment composition	Abundance
Particle size	Biomass
Organic and inorganic matter	Taxon diversity
Carbonate content	Waterfowl
Nitrogen and phosphorous	Relative abundance
Water chemistry	Species diversity
Dissolved oxygen	
Temperature	
pH	
Specific conductivity	
Turbidity	
Alkalinity	
Color	
Total suspended solids	
Volatile suspended solids	
Total and dissolved organic carbon	
Nutrients	
Total and dissolved N, P	
Orthophosphate	
Ammonium	
Nitrate+nitrite	
Cations (Ca, Mg, Na, K)	
Anions (SO_4, Cl)	
Chlorophyll a (phytoplankton biomass)	

1. Cowardin, L. M., Gilmer, D. S. and Mechlin, L. M. (1981) Characteristics of central North Dakota wetlands determined from sample aerial photographs and ground study. Wildl. Soc. Bull. 9,280-88.

2. Grue, C. E., DeWeese, L. R., Mineau, P., Swanson, G. A., Foster, J. R., Arnold, P. M., Huckins, J. N., Sheehan, P. L., Marshall, W. K. and Ludden, A. P. (1986) Potential impacts of agricultural chemicals on waterfowl and other wildlife inhabiting prairie wetlands: An evaluation of research needs and approaches. Trans. N. Am. Wildl. Nat. Resour. Conf. 51,357-383.

3. Grue, C. E., Tome, M. W., Messmer, T. A., Henry, D. B., Swanson, G. A. and DeWeese, L. R. (1989) Agricultural chemicals and prairie pothole wetlands: meeting the needs of the resource and the farmer - U. S. perspective. Trans. N. Am. Wildl. Nat. Resour. Conf. 54,43-58.

4. Martin, D. B. and Hartman, W. A. (1987) The effect of cultivation on sediment composition and deposition in prairie pothole wetlands. Water, Air, and Soil Poll. 34,45-53.

5. Dieter, C. D. (1991) Water turbidity in tilled and untilled prairie wetlands. J. Fresh Water Ecol. 6,185-189.

6. Detenbeck, N. E., Elonen, C. and Taylor, D. L. (1996) Spatial and temporal variability of water quality of wetlands in the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

7. Taylor, D. L. and Detenbeck, N. E. (1996) Effects of water level changes on prairie pothole vegetation structure and diversity in the Woodworth Study Area, North Dakota. Proc. N.D. Acad. Sci. 50.

8. Vieux, B. E., Freeman, G. E., LeDimet, E. and Guinepain, S. (1996) Hydrologic and sedimentation simulation in the prairie pothole region of North Dakota. Proc. N.D. Acad. Sci. 50.

9. Wrubleski, D. (1996) Chironimidae (Diptera) of the Woodworth Study Area, North Dakota. Proc. N.D. Acad. Sci. 50.

10. U.S. Soil Conservation Service (1988) Filter Strip. Soil Conservation Practice 393, Technical Guide Notice ND-95.

11. Stewart, R. E. and Kantrud, H. A. (1971) Classification of natural pond and lakes in the glaciated prairie region. U.S. Fish Wildl. Serv. Resour. Publ. 92.

12. Stewart, R. E. and Kantrud, H. A. (1973) Ecological distribution of breeding waterfowl populations in North Dakota. J. Wildl. Manage. 37,39-50.

13. Kantrud, H. A., Krapu, G. L. and Swanson, G. A. (1989) Prairie basin wetlands of the Dakotas: a community profile. U.S Fish Wildl. Serv. Biol. Rep. 85(7.28).

14. Cowardin, L. M., Shaffer, T. L. and Arnold, P. M. (1995) Evaluation of duck habitat and estimation of duck populations sizes with a remote-sensing-based system. National Biological Service, Biological Science Report No. 2.

15. Johnson, D. H., Higgins, K. F. and Woodward, R. O. (1996) An introduction to the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

16. U.S. Natural Resources Conservation Service. (1995) Soil survey of Stutsman County, North Dakota. U.S. Department of Agriculture.

17. Gardner, W. D. (1980) Field assessment of sediment traps. J. Mar. Res. 38,41-52.

18. Blomqvist, S. and Håkanson, L. (1981) A review of sediment traps in aquatic environments. Arch. Hydrobiol. 91,101-132.

19. Reed, D. J. (1989) Patterns of sediment deposition in subsiding coastal salt marshes, Terrebonne Bay, Louisiana: The role of winter storms. Estuaries 12,222-227.

20. Cahoon, D. R. and Turner, R. E. (1989) Accretion and canal impacts in a rapidly subsiding wetland II. Feldspar marker horizon technique. Estuaries 12,260-268.

21. Sheridon, J. M, Lowrance, R. R. and Henry, H. H. (1996) Surface flow sampler for riparian studies. Appl. Eng. in Agricul. (In Press).

SPATIAL AND TEMPORAL VARIABILITY OF WATER QUALITY OF WETLANDS IN THE WOODWORTH STUDY AREA

Naomi E. Detenbeck*, Colleen M. Elonen, and Debra L. Taylor
U.S. Environmental Protection Agency
Mid-Continent Ecology Division
6201 Congdon Boulevard, Duluth, MN 55804

Seasonal prairie pothole wetlands play a critical role in supporting waterfowl production in the Prairie Pothole Region, particularly for early-nesting species. This wetland class also is at high risk to degradation or loss from agricultural stressors such as drainage, tillage through wetland basins, nonpoint source sediment and nutrient inputs from agricultural uplands, and pesticide overspray or spray drift. Twenty seasonal prairie pothole wetlands in the Woodworth Study Area and surrounding waterfowl production areas were selected for a collaborative study of the physical, chemical, and biological effects of summer fallow practices, best management practices (vegetated buffer strips), upland restoration through the Conservation Reserve Program (CRP), and preservation of wetlands within native prairie (NP) watersheds (1). The study period extended from the end of a prolonged drought through two abnormally wet years, so that the originally seasonally-flooded wetlands were converted to semi-permanently flooded basins.

Water quality of study wetlands was monitored on a monthly basis (May-September) during 1993 and 1994 both prior to and following implementation of summer fallow treatments. Variables measured included temperature, dissolved oxygen, specific conductance, apparent color, turbidity, total and volatile suspended solids, phosphorus (soluble reactive, dissolved, and total), nitrogen (ammonium, nitrate + nitrite, dissolved and total), organic carbon (dissolved and total), and major ions (Ca, Mg, Na, K, SO_4, Cl, F, Br). Ratios of soluble reactive P to dissolved inorganic N (SRP:DIN), particulate P:N, and total P:N were calculated as indicators of relative P:N nutrient limitation for algae and grazers, respectively. Ratios of Cl: specific conductivity were calculated to determine whether changes in specific conductivity (and major ions) were due to simple evapotranspiration or to other biogeochemical processes. In addition, occasional diurnal measurements were made of pH, conductivity, temperature, dissolved oxygen, and turbidity using automated water quality recorders (Hydrolabs). Water quality variables were analyzed using multivariate analysis of variance (MANOVAs) to determine if any significant differences existed among treatment classes prior to treatment. Treatment and time effects for 1993-1994 were analyzed using a repeated measures design. Only differences between native prairie (NP) and restored upland (CRP) treatments, and differences due to interannual climatic variability will be discussed here.

No pretreatment differences among treatment classes were detected for any of the water quality variables analyzed ($P < 0.05$). Water quality data were highly variable among sites and over time, ranging over approximately two orders of magnitude for soluble reactive P, dissolved and total P, total suspended solids, Gran alkalinity, magnesium, sodium, chloride, and sulfate (Table 1). Only dissolved phosphorus, turbidity, surface dissolved oxygen, potassium, and ratios of chloride:specific conductivity and soluble reactive P: dissolved inorganic N showed significant differences between CRP and NP treatments ($P < 0.05$). Of these variables, all but surface D.O. and the Cl:conductivity ratio were greater on average for the CRP sites. N:P ratios showed evidence for nitrogen limitation in 1993, but shifted towards phosphorus limitation in 1994, following increases in water depth. Dissolved oxygen decreased to near zero as depth and duration of flooding increased and wetlands became stratified; however, diurnal oxygen profiles were strongly modified by vegetation structure within sites.

Table 1. Water quality values for twenty wetlands in the Woodworth Study Area, 1993-1994. Wetlands were classified as seasonally-flooded in previous years, but were converted to semi-permanently flooded wetlands due to above-normal precipitation. Wetlands in the following treatment classes are included: native prairie, restored upland (CRP), tilled watershed with vegetated buffer strips, and summer fallow watersheds.

Water quality variable	Units	1993	1994
Soluble reactive phosphorus	mG P/L	0.19-3.21	<0.01-3.59
Dissolved phosphorus	mG P/L	0.12-3.89	<0.02-3.63
Total phosphorus	mG P/L	0.11-6.11	0.07-3.44
Particulate phosphorus	mG P/L	<0.02-3.16	<0.02-1.25
Nitrate-N	μG N/L	<28-118	<32-75
Total ammonia-N	μG N/L	<22-1835	<34-678
Dissolved nitrogen	mG N/L	1.11-9.80	0.84-4.32
Total nitrogen	mG N/L	0.99-9.62	1.01-5.07
Particulate nitrogen	mG N/L	<0.12-3.07	<0.30-2.09
Dissolved organic carbon	mG C/L	19-138	<3.2-52
Total organic carbon	mG C/L	19-130	14-54

Table 1. **(continued).**

Water quality variable	Units	1993	1994
Particulate organic carbon	mG C/L	<3.1-26.6	<3.6-30.4
Apparent color	PCU	162-1334	66-411
Turbidity	NTU	<1.2-332	<0.6-26.1
Total suspended solids	mG/L	<1-138	<1.8-107
Volatile suspended solids	mG/L	1-155	1.8-87.5
Specific conductivity @ 25°C	µmhos/cm	132-1097	150-2710
pH	log [H^+]	6.6-8.2	6.1-8.5
Gran alkalinity	mG $CaCO_3$/L	41-317	6-505
Calcium	mG/L	6-101	11-119
Magnesium	mG/L	<1.4-64	3-189
Sodium	mG/L	0.3-7.2	<0.1-208
Potassium	mG/L	8-45	5-43
Sulfate	mG/L	0.3-389	<2-1472
Chloride	mG/L	1-14.5	0.3-13
Bromide	mG/L	<0.09-7.17	<0.2-0.4
Fluoride	mG/L	0.05-0.24	<0.1-0.21

There were significant treatment x time interactions involving NP and CRP sites for soluble reactive P, total P, dissolved and total N, TP:TN and total organic C. Nutrient levels declined more over the period of the study for NP sites as compared to CRP sites, possibly related to differences in D.O. levels. In contrast, water levels increased more over time for NP sites as compared to CRP sites ($P< 0.05$). Water levels were constrained by the elevation of surface water outlets for three of the CRP sites, although the two sites with lowest average water depths in 1994 did not develop outlets (1).

In conclusion, our site selection process was successful in enabling us to prevent initial biases in water quality conditions among wetland treatment classes, although high variability will limit our ability to detect treatment effects on prairie pothole water quality over time. Of the water quality variables studied, phosphorus, suspended solids, and major ions were the most variable over time and space. Temporal trends (decreased dissolved oxygen, increased N:P ratios) appeared to be linked to changing water depths. Differences in water quality between NP and CRP sites were not apparent at the beginning of the study, but increased over time, possibly because of differing hydrologic responses; this accentuates the importance of long-term ecosystem studies covering more than one growing season. Differences between NP and CRP sites suggest that historical differences in land-use treatments can have significant impacts on water quality of prairie pothole wetlands. These differences need to be considered when designing whole watershed experiments.

1. Gleason, R. A. and Euliss, N. H., Jr. (1996) Impact of agriculutral land-use on prairie wetland ecosystems: experimental design and overview. Proc. N.D. Acad. Sci. 50.

EFFECTS OF WATER LEVEL CHANGES ON PRAIRIE POTHOLE VEGETATION STRUCTURE AND DIVERSITY IN THE WOODWORTH STUDY AREA, NORTH DAKOTA

Debra L. Taylor* and Naomi E. Detenbeck
U.S. Environmental Protection Agency
Mid-Continent Ecology Division
6201 Congdon Boulevard
Duluth, MN 55804

INTRODUCTION AND METHODS

Vegetation diversity and community structure were monitored in 1993 and 1994 in 20 seasonal wetlands near Woodworth, ND. These wetlands were the site of a three-year study examining the effects of agricultural practices and sedimentation on seasonal prairie wetlands. The wetlands were chosen for similar area (mean 0.18 ha, range 0.09 to 0.47 ha) similar watershed size (range 0.49 to 2.18 ha), and none had surface water inlets or outlets at the beginning of the study. Radial transects were established in each wetland in April 1993 when shallow marsh and wet meadow zones were delineated. In May 1993, five wetland watersheds were tilled to the wet meadow/upland boundary. In addition, another five watersheds were tilled but 25 ft (7.62 m) buffer zones were left around these wetlands. Five wetlands were native prairie, and the final five had been managed for Conservation Reserve Program vegetation for at least ten years. During the 1993 and 1994 growing seasons, vegetation density and diversity in each wetland was measured using the point-centered quarter method (1). Densities were measured separately for species within each of five growth form categories: shrubs, forbs, graminoids, giant burreed (*Sparganium eurycarpum*), and cattails (*Typha* spp.). The graminoid growth form included grass, sedge, and rush species. These vegetation surveys were conducted in June and September 1993 and in May, June, and July 1994.

Water levels at the deepest point in each wetland ranged from 1 cm to 62 cm (mean 26 cm) in June 1993. Soon after the June 1993 survey, unusually high rainfall began in the Woodworth area. This increased precipitation continued through the autumn; precipitation in winter and spring, 1994 was also higher than normal. By June 1994, the 20 study wetlands had water depths of 29 cm to 130 cm (mean 80 cm). Water levels in most of the wetlands did not drop significantly in mid-summer 1994. The mean July depth was 78 cm, with a range of 20 to 131 cm.

Vegetation of the five native prairie (NP) and the five Conservation Reserve Program (CRP) sites will be described here. June 1993 data will be compared with both the June 1994 and July 1994 observations. High water levels and the cool spring temperatures in 1994 retarded plant growth. Thus, the July 1994 observations may better represent peak summer biomass for 1994.

RESULTS

Vegetation density decreased overall and mean plant height increased between June 1993 and June/July 1994 in response to the increased water levels. Community structure in both the shallow marsh and wet meadow zones changed between summer 1993 and summer 1994. Species generally associated with semi-permanent wetlands, such as cattail and giant burreed, became established in the centers of several wetlands by July 1994, although none of these species became dominant in any wetland. No submersed vegetation was found in any wetland in June 1993. However, a submersed species, bladderwort, (*Utricularia vulgaris*) was found in five of the ten NP/CRP wetlands during the summer of 1994.

In June 1993, the average water depth at the deepest point in the NP sites was 31 cm (Table 1). This had increased to 106 cm in June 1994, and was measured at 103 cm in July 1994. The CRP wetlands tended to be shallower than the NP sites throughout the study, with a mean water depth of 15 cm in June 1993, 49 cm in June 1994 and 46 cm in July 1994.

In the NP sites, percent open water in the shallow marsh zones increased from 61% in June 1993 to 81% in July 1994 (Table 1). Virtually no open water existed in the wet meadow zones of the NP wetlands in June 1993; open water covered 69% of the area in June 1994 and 46% a month later in July. The percent open water in the shallow marsh zones of CRP sites remained fairly constant during the 1993 and 1994 growing seasons. The CRP wet meadow zones showed an increase in open water area, from 8% in June 1993 to 25% in June and 20% in July 1994.

Overall vegetation density, defined as shoots/m^2, decreased in both the NP and the CRP wetlands (Table 1). In the NP shallow marsh zones, graminoids showed little decrease in density between June 1993 and June 1994. However, by July 1994, the graminoid density in the shallow emergent zones of NP wetlands had decreased significantly. Forbs showed large decreases in density after flooding. In the wet meadow zones of the NP sites, graminoids dropped to a third of their June 1993 density by June/July 1994. Forbs also decreased in density, thinning from 272 to 28 shoots/m^2.

Graminoid density decreased in both vegetation zones in the CRP wetlands. Shallow marsh zone forbs showed a small drop, from 123 to 88 shoots/m^2 (Table 1). The density of forbs actually increased in the CRP wet meadow zones, from an average of 126 shoots/m^2 to 186 shoots/m^2 in July, 1994, largely due to increased densities of water smartweed (*Polygonum amphibium*).

Table 1. Water depth, percent cover and average vegetation height, pre- and post-flooding. NP = native prairie, CRP = Conservation Reserve Program, SE = shallow emergent/shallow marsh zone, WM = wet meadow zone.

Parameter	Date 6/93	6/94	7/94
Water Depth (cm)			
Aver. deepest pt , NP sites[1]	31	106	103
Aver. deepest pt , CRP sites[1]	15	49	46
Vegetative Cover (%)			
NP open water SE	61	80	81
NP open water WM	0	69	46
CRP open water SE	35	53	41
CRP open water WM	8	25	20
Vegetation Density (shoots/m^2)			
NP SE graminoid	114	107	34
NP SE forb	93	32	19
NP WM graminoid	695	211	218
NP WM forb	272	48	28
CRP SE graminoid	526	94	86
CRP SE forb	123	98	88
CRP WM graminoid	1533	436	514
CRP WM forb	126	263	186
Aver. Vegetation Height (cm)			
NP SE	32	110	114
NP WM	20	67	82
CRP SE	33	79	85
CRP WM	35	58	72

[1]Average of the water depths at the deepest points in the five NP or CRP wetlands, for each month stated.

In both the NP and the CRP sites, nearly all the area that was not open water was covered by live, erect vegetation. Bare earth, filamentous algae, and/or floating-leaf vegetation constituted no more than 5.5% of the cover in any of these sites during any of the three sampling periods.

Vegetation heights increased in both the shallow marsh and wet meadow zones in the NP and in the CRP sites (Table 1). In the NP sites, average vegetation heights in both vegetation zones increased about 300% after flooding. For the CRP sites, with shallower water depths, the vegetation height increases were not as great, averaging 200 to 250%.

The average number of species with ten or more shoots/m^2 decreased in both the shallow marsh and wet meadow zones of the NP sites during the study period. For the shallow marsh zone, the decrease was from an average of 5.4 species in June 1993 to 1.2 species in June and July 1994. In the NP wet meadow zones, the decrease was from 7.0 species in June, 1993 to 5.0 species in June 1994, and a further decrease to 3.6 species by July 1994.

The decrease in the average number of species with at least ten shoots/m^2 in the CRP wetlands was not nearly as great, from 5.6 to 3.8 species in the shallow marsh zones and 7.8 to 6.6 species in the wet meadow zones.

In the shallow marsh zones of the NP sites, slough sedge (*Carex atherodes*) and whitetop (*Scolochloa festucacea*) replaced quack grass (*Agropyron repens*) and a number of forbs following the water level rise (Table 2). Water smartweed was the only forb whose densities exceeded 10 shoots/m^2 during the summer of 1994.

In the shallow marsh zones of the CRP sites, whitetop and river bulrush (*Scirpus fluviatilis*) replaced brome grass (*Bromus inermis*), reed canary grass (*Phalaris arundinacea*), spikerush (*Eleocharis palustris*), and alkali-grass (*Puccinellia nuttalliana*) (Table 2). Sedge species (including *C. atherodes*) and quack grass were found in the CRP shallow marsh zones during both study years. Dominant forbs shifted to wetter-zone species (2).

Table 2. Species present by treatment, zone and month. Includes only species with densities greater than 10 shoots/m².

Treatment	Growth Form	Veg Zone	Taxon	6/93	6/94	7/94
NP	G	SE	*Carex* sp.	693	uncertain	uncertain
NP	G	SE	*Agropyron repens*	693		
NP	G	SE	*Scolochloa festucacea*		694	794
NP	G	SE	*Carex atherodes*		694	794
NP	F	SE	*Polygonum amphibium*	693	694	794
NP	F	SE	*Aster simplex*	693		
NP	F	SE	*Aster* sp.	693		
NP	F	SE	*Solidago altissima*	693		
NP	F	SE	*Solidago* sp.	693		
NP	F	SE	*Sonchus arvensis*	693		
NP	F	SE	*Artemisia absinthium*	693		
NP	F	SE	*Cirsium arvense*	693		
NP	F	SE	*Urtica dioica* ssp. *gracilis*	693		
NP	F	SE	*Atriplex patula*(=hastata)	693		
NP	F	SE	*Anemone canadensis*	693		
CRP	G	SE	*Carex atherodes*	693	694	794
CRP	G	SE	*Agropyron repens*	693	694	794
CRP	G	SE	*Carex* sp.	693		794
CRP	G	SE	*Poaceae*	693		794
CRP	G	SE	*Eleocharis palustris*	693		
CRP	G	SE	*Bromus inermis*	693		
CRP	G	SE	*Phalaris arundinacea*	693		
CRP	G	SE	*Puccinellia nuttalliana*	693		
CRP	G	SE	*Scolochloa festucacea*		694	794
CRP	G	SE	*Scirpus fluviatilis*			794
CRP	F	SE	*Polygonum amphibium*	693	694	794
CRP	F	SE	*Urtica dioica* ssp. *gracilis*	693		
CRP	F	SE	*Taraxacum officinale*	693		
CRP	F	SE	*Sonchus arvensis*	693		
CRP	F	SE	*Rumex mexicanus*	693		
CRP	F	SE	*Cirsium arvense*	693		
CRP	F	SE	*Aster* sp.	693		
CRP	F	SE	*Alisma plantago-aquatica*		694	794
CRP	F	SE	*Rorippa islandica* (=palustris)			794
CRP	BR	SE	*Sparganium eurycarpum*			794
NP	S	WM	*Symphoricarpos occidentalis*	693		
NP	G	WM	*Agropyron repens*	693	694	794
NP	G	WM	*Carex* sp.	693	694	794
NP	G	WM	*Poaceae*	693	694	794
NP	G	WM	*Eleocharis palustris*/ E. spp.	693	694	794
NP	G	WM	*Calamagrostis canadensis*	uncertain	694	794
NP	G	WM	*Carex vulpinoidea*	uncertain	694	uncertain
NP	G	WM	*Carex lanuginosa*	uncertain	694	uncertain
NP	G	WM	*Juncus balticus*	693	694	
NP	G	WM	*Poa pratensis*	693		
NP	G	WM	*Bromus inermis*	693		
NP	G	WM	*Spartina pectinata*		694	794
NP	G	WM	*Scolochloa festucacea*		694	794
NP	G	WM	*Carex atherodes*		694	794

Table 2. **(continued).**

Treatment	Growth Form	Veg Zone	Taxon	6/93	6/94	7/94
NP	G	WM	*Phalaris arundinacea*		694	
NP	F	WM	*Sonchus arvensis*	693	694	
NP	F	WM	*Cirsium arvense*	693		
NP	F	WM	*Anemone canadensis*	693		
NP	F	WM	unknown forb	693		
NP	F	WM	*Stachys palustris*	693		
NP	F	WM	*Taraxacum officinale*	693		
NP	F	WM	*Aster simplex*	693		
NP	F	WM	*Solidago gigantea*	693		
NP	F	WM	*Solidago* sp.	693		
NP	F	WM	*Aster* sp.	693		
NP	F	WM	*Polygonum amphibium*		694	794
NP	F	WM	*Suaeda depressa*		694	
CRP	G	WM	*Bromus inermis*	693	694	794
CRP	G	WM	*Phalaris arundinacea*	693	694	794
CRP	G	WM	*Agropyron repens*	693	694	794
CRP	G	WM	*Carex* sp.	693	694	794
CRP	G	WM	*Carex lanuginosa*	uncertain	694	uncertain
CRP	G	WM	*Carex vulpinoidea*	uncertain	694	uncertain
CRP	G	WM	*Poa pratensis*/*Poa* sp.	693	694	
CRP	G	WM	*Puccinellia nuttalliana*	693		
CRP	G	WM	*Eleocharis palustris*	693		
CRP	G	WM	*Carex atherodes*		694	794
CRP	G	WM	*Scirpus fluviatilis*/*Scirpus* sp.		694	794
CRP	G	WM	*Poaceae*		694	794
CRP	G	WM	*Juncus interior*		694	
CRP	G	WM	*Spartina pectinata*			794
CRP	G	WM	*Juncus balticus*			794
CRP	F	WM	*Polygonum amphibium*	693	694	794
CRP	F	WM	*Anemone canadensis*	693	694	794
CRP	F	WM	*Solidago gigantea*/*S.* sp.	693	694	
CRP	F	WM	*Ranunculus macounii*/*R.* sp.	693	694	
CRP	F	WM	*Mentha arvensis*	693		794
CRP	F	WM	*Cirsium arvense*	693		794
CRP	F	WM	*Urtica dioica* ssp. *gracilis*	693		794
CRP	F	WM	*Rumex mexicanus*	693		
CRP	F	WM	*Taraxacum officinale*	693		
CRP	F	WM	unknown forb	693		
CRP	F	WM	*Brassicaceae*	693		
CRP	F	WM	*Artemisia absinthium*	693		
CRP	F	WM	*Sonchus arvensis*		694	794
CRP	F	WM	*Stachys palustris*		694	794
CRP	F	WM	*Sonchus asper*		694	
CRP	F	WM	*Glycyrrhiza lepidota*		694	
CRP	F	WM	*Suaeda depressa*		694	
CRP	F	WM	*Lysimachia* sp.		694	
CRP	F	WM	*Potentilla norvegica*		694	
CRP	F	WM	*Aster* sp.		694	
CRP	F	WM	*Aster praealtus*		uncertain	794
CRP	F	WM	*Aster junciformis*		uncertain	794

In the wet meadow zones of the NP sites, brome grass and fowl bluegrass (*Poa palustris*) were succeeded by slough sedge, reed canary grass, whitetop, and prairie cordgrass (*Spartina pectinata*) (Table 2). Forbs changed from a mixture of Canadian thistle (*Cirsium* *arvense*), goldenrods (*Solidago spp.*), asters (*Aster spp.*), anemone (*Anemone canadensis*), woundwort (*Stachys palustris*), and dandelion (*Taraxacum officinale*) to water smartweed and sea blite (*Suaeda depressa*). At least five graminoids and sow thistles (*Sonchus arvensis*) were found in the NP wet meadow zones during both years. The most common shrub, wolfberry (*Symphoricarpos occidententalis*), died out as the water levels rose.

Four species of grass and a number of small sedges were present in the CRP wet meadow zones in 1993 and again in 1994 (Table 2). Spikerush and alkali-grass were found only in 1993. After the water levels rose, these graminoids were replaced by slough sedge, true rush (*Juncus balticus*, *J. interior*), prairie cordgrass, bulrush (*Scirpus spp.*) and a small, stunted, unidentifiable grass. As in the NP sites, wet meadow forbs also moved toward more hydrophytic species, but the effect was not as pronounced in the CRP sites.

DISCUSSION

When emergent wetland vegetation is subjected to an increase in water level, either the emergent vegetation is largely eliminated, or vegetation zones migrate up slope toward more optimal water depths (3). van der Valk (3) suggests that the die-out model is more likely to apply to large and/or abrupt water level increases, while the migration theory is more likely to prove true when water level increases are small or occur gradually over a number of years. Shallow emergent prairie pothole vegetation (sedges, water smartweed, whitetop, spikerush) is adapted to seasonal wetlands, which have an annual wet/dry cycle. Millar (4) observed that shallow marsh vegetation will experience at least a partial die-off after one winter of standing water conditions.

In this study, water levels increased substantially in one year. We saw more evidence of drier end species dying out than evidence of emergent vegetation migrating up slope (vegetation densities decreased in both the shallow emergent and wet meadow zones, per cent open water increased in the NP wetlands). Although the dominance of several shallow marsh species (slough sedge, whitetop, water smartweed) increased with flooding, their overall densities decreased by July of 1994.

The combined decrease in density and increase in vegetation height is consistent with the conclusions of Squires and van der Valk (5). They stated that for emergent species to survive in increased water depths, the plants must be able to maintain sufficient area above the water surface for gas exchange. To accomplish this, emergent plant species tend to produce fewer and longer shoots, which results in increased height and decreased density.

An examination of Table 2 shows an overall shift from drier end grasses and forbs to slough sedges, whitetop, water plantain (*Alisma plantago-aquatica*), bulrush, and burreed in the shallow emergent zones. Smaller and less water-tolerant forbs had lower chances for survival than forbs adapted for standing water conditions (water plantain, water smartweed). The rising water table killed shrubs in the wet meadow zones of the NP sites.

When compared to the CRP sites, the NP sites were deeper overall and had a greater percent of open water in their wet meadow zones. Predictably, the wet meadow zones of the NP wetlands showed a more dramatic change to wetter-zone, shallow marsh-type species than did the species mix in the CRP wet meadow zones (2).

Also, the decrease in vegetation diversity was more obvious in the NP sites. This, too, may be due to the greater post-flooding water depths in the NP sites. It is possible that more species were able to survive the shallower inundation depths found in the CRP wetlands (5).

The presence of bladderwort, after only one year of continuous flooding, is consistent with the findings of Millar (4) who concluded that bladderwort was one of the first submerged species to become established under conditions of year-round inundation.

---

1. Barbour, M. G., Burk, J. H. and Pitts, W. D. (1987) Terrestrial Plant Ecology, 2nd ed. The Benjamin/Cummings Publishing Company, Menlo Park, CA.

2. Great Plains Flora Association, McGregor, R. L., Coordinator (1991) Flora of the Great Plains. University Press of Kansas, Lawrence.

3. van der Valk, A. G. (1994) Effects of prolonged flooding on the distribution and biomass of emergent species along a freshwater wetland coenocline. Vegetatio 110,185-196.

4. Millar, J. B. (1972) Vegetation changes in shallow marsh wetlands under improving moisture regime. Can. J. Bot. 51,1443-1457.

5. Squires, L. and van der Valk, A. G. (1992) Water-depth tolerances of the dominant emergent macrophytes of the Delta Marsh, Manitoba. Can. J. Bot. 70,1860-1867.

CHIRONOMIDAE (DIPTERA) OF THE WOODWORTH STUDY AREA, NORTH DAKOTA

Dale Wrubleski*
U.S. Environmental Protection Agency
Mid-Continent Ecology Division
6201 Congdon Boulevard
Duluth, MN 55804

INTRODUCTION

The Chironomidae are a numerically dominant group of aquatic insects in prairie wetland habitats, and have also been reported to be important in food chain support (1). However, we know very little about chironomid species composition, relative abundances, or phenologies. Descriptions of prairie pothole chironomid communities have been provided by Driver (2) and Parker (3, 4) for sites in Saskatchewan. In North Dakota, only Nelson (5) has described the chironomid community of prairie potholes, but only information for the two dominant species is provided, along with a list of the 14 genera collected.

As part of a larger study examining the effects of sedimentation on chironomid production in prairie wetlands, emergence traps were placed in 10 study wetlands to help in determining species identification and life cycle patterns. This paper presents the emergence trap results for 1994, the second year of watershed manipulations.

METHODS AND MATERIALS

This study took place in wetlands associated with the sedimentation study described by Gleason and Euliss (6). Ten of the twenty wetlands were selected for study, five wetlands with their watersheds in the Conservation Reserve Program (CRP) and five with tilled watersheds. For the purposes of this paper, watershed treatments will not be considered further.

Emergence traps used were a modified version of trap 1 described by Nelson (5) which sampled a surface area of $0.1m^2$. Three traps were set randomly within each wetland adjacent to previously established transects. Traps were initially set on 3 June and operated continuously until 8 September, 1994. As sites dried, due to declining water levels, traps were moved to deeper water. Wetland 2401 was dry by the end of July, and wetlands 13E2 and 0724 were dry by the end of August. Traps were emptied weekly, cleaned, and rotated around their support post to prevent continual collection over the same substrate.

Samples were preserved in 70% ethyl alcohol. Representative specimens of each species were mounted on glass slides in Euparol for identification. Voucher specimens will be deposited with the National Biological Service, Northern Prairie Science Center, Jamestown, North Dakota and the U.S. Environmental Protection Agency, Mid-Continent Ecology Laboratory, Duluth, Minnesota.

RESULTS AND DISCUSSION

Peak chironomid emergence took place in May, before emergence sampling was initiated (Figure 1). Emergence declined through to the end of June and then remained at very low numbers through the rest of the summer. Nelson (5) also reported peak emergence in May from two semi-permanent wetlands at Cottonwood Lake, but he observed almost no emergence after the end of June.

Table 1 lists the 30 identified species of chironomids collected during 1994. Eventual identification of several undetermined specimens will probably increase this number slightly. Overall, this number is low compared to several other studies in prairie wetland habitats. For example, Driver (2) listed 48 species from 16 ponds sampled over a three-year period in central Saskatchewan. Parker (4) reported 43 species of Chironomidae collected over a three-year period from a single prairie pond, also in Saskatchewan. Wrubleski and Rosenberg (7) collected 84 species from the much larger Delta Marsh in Manitoba. The lower number of species found in the present study is probably more a reflection of sampling effort than real differences. Samples from the Woodworth wetlands are only from part of one year, whereas the other studies sampled over a number of years.

The number of chironomid species present within individual Woodworth wetlands averaged 16 (range 9-23). This number is close to the mean of 20 species that Driver (2) reported for semi-permanent wetlands in Saskatchewan. He observed that seasonal wetlands had a mean of only 5 species. Although initially selected as seasonal wetlands, high levels of precipitation in 1993 and 1994 raised water levels considerably, resulting in most wetlands becoming semi-permanent, except for the three ponds that did go dry in late summer. Consequently, the numbers of chironomid species present in the Woodworth wetlands is reflective of the increased water levels.

Increases in water levels affect the structure of the chironomid communities in prairie wetlands in several ways. First, species that would otherwise not be able to complete development in seasonal wetlands, because of the short period of flooding, are now capable of doing so due to the greater length of flooding. In addition, deep water over the winter period will modify overwintering conditions and

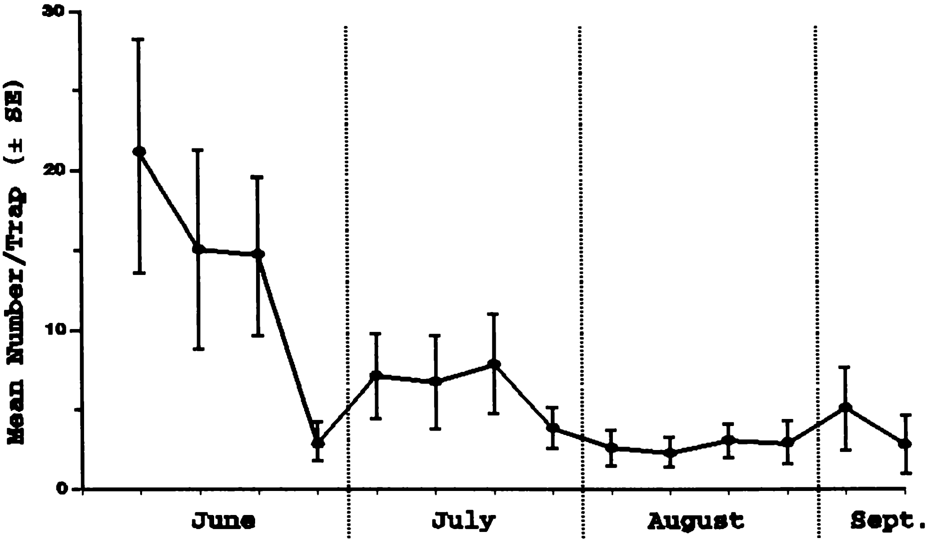


Figure 1. Seasonal trend in mean weekly emergence (no./trap ± SE) for total Chironomidae from Woodworth wetlands, 1994.

the survival of chironomid larvae within bottom sediments. Water bodies that freeze completely during winter, termed "aestival", have lower numbers of chironomid species than when water levels are deeper (4, 8). The increased water levels also flooded considerable amounts of terrestrial vegetation, creating conditions favorable to increased chironomid habitat (9).

The chironomid community present in the Woodworth wetlands is very different from that found in two semi-permanent wetlands at Cottonwood Lake, just 10 miles away (5). The most abundant species collected from the Woodworth wetlands were: *Corynoneura* sp. 1, *Chironomus pallidivittatus*, *Tanytarsus* sp. 1, *Psectrotanypus dyari* and *Chironomus atrella*. *Chironomus tentans* and *Glyptotendipes* nr. *paripes* were dominant species at the Cottonwood Lake wetlands. *Chironomus tentans* was present in Woodworth wetlands, but in very low numbers. Also, four species of *Chironomus* were found at Woodworth, whereas only one was found at Cottonwood Lake. Three species of *Glyptotendipes* were found at Woodworth but only one species was found at Cottonwood Lake, and none of these species were shared by both areas. The disparities between these two areas is not unusual, as other studies have also reported very different chironomid communities between wetland areas (4, 10). These differences have been attributed to such features as pond permanency, water chemistry, and aquatic plant communities (2, 7).

Although the numbers of chironomid species present in prairie wetlands may be predictable, based on pond permanency for example (2), species composition and their relative abundances are not. Further studies are needed to understand how biotic and abiotic factors structure chironomid communities in prairie wetlands. This information is particularly important if we are to accurately assess anthropogenic impacts in these habitats.

Table 1. **Species of Chironomidae and mean emergence (number/m²) obtained by emergence traps from 10 wetlands at the Woodworth Study Area, North Dakota, 3 June to 8 September, 1994.**

	Mean no./m²
Tanypodinae	137.0
Ablabesmyia sp. 1	23.7
Ablabesmyia sp. 2	1.0
Ablabesmyia sp. 3	13.3
Psectrotanypus dyari (Coq.)	94.7
Procladius bellus (Loew)	3.3
Tanypus punctipennis Meig.	0.3
Orthocladiinae	257.3
Acricotopus nitidellus (Mall).	7.7
Corynoneura sp. 1	173.7
Corynoneura sp. 2	14.0
Cricotopus ornatus (Meig.)	15.3
Cricotopus sp. 2	1.0
Limnophyes sp.	4.0
Psectrocladius sp. 1	34.3
Psectrocladius sp. 2	5.7
Chironominae	
Chironomini	389.3
Chironomus tentans Fab.	9.7
Chironomus pallidivittatus Mall.	114.3
Chironomus riparius Meig.	8.7
Chironomus atrella (Town.)	90.7
Dicrotendipes sp.	17.3
Endochironomus nigricans (Joh.)	17.3
Glyptotendipes barbipes (Staeg.)	80.0
Glyptotendipes lobiferus (Say)	1.7
Glyptotendipes sp. 3	2.7
Parachironomus potamogeti (Town.)	45.0
Tanytarsini	195.7
Cladotanytarsus sp.	1.3
Micropsectra sp.	0.7
Paratanytarsus spp.	18.0
Tanytarsus sp. 1	113.3
Tanytarsus sp. 2	46.3
Tanytarsus sp. 3	15.0
Unidentified	5.0
Total Chironomidae	979.0

1. Wrubleski, D. A. (1987) Chironomidae (Diptera) of peatlands and marshes in Canada, pp. 141-161. *In*: Rosenberg, D. M. & H. V. Danks (eds.). Aquatic insects of peatlands and marshes in Canada. Mem. Entomol. Soc. Canada 140.

2. Driver, E. A. (1977) Chironomid communities in small prairie ponds: some characteristics and controls. Freshwat. Biol. 7,121-133.

3. Parker, D. W. (1985) Biosystematics of Chironomidae (Diptera) inhabiting selected prairie ponds in Saskatchewan. M.S. thesis, University of Saskatchewan, Saskatoon.

4. Parker, D. W. (1992) Emergence phenologies and patterns of aquatic insects inhabiting a prairie pond. Ph.D. thesis, University of Saskatchewan, Saskatoon.

5. Nelson, R. D. (1989) Seasonal abundance and life cycles of chironomids (Diptera: Chironomidae) in four prairie wetlands. Ph.D. thesis, North Dakota State University, Fargo.

6. Gleason, R. A. and Euliss, N. H., Jr. (1996) Impact of agricultural land-use on prairie wetland ecosystems: experimental design and overview. Proc. N.D. Acad. Sci. 50.

7. Wrubleski, D. A. and Rosenberg, D. M. (1990) The Chironomidae (Diptera) of Bone Pile Pond, Delta Marsh, Manitoba, Canada. Wetlands 10,243-275.

8. Daborn, G. R. (1974) Biological features of an aestival pond in western Canada. Hydrobiologia 44,287-299.

9. Wrubleski, D. A. (1991) Chironomidae (Diptera) community development following experimental manipulation of water levels and aquatic vegetation. Ph.D. thesis, University of Alberta, Edmonton.

10. Morrill, P. K. (1988) Disturbance of pond Chironomidae communities by deltamethrin insecticide. M.S. thesis, University of Saskatchewan, Saskatoon.

HYDROLOGIC AND SEDIMENTATION SIMULATION IN THE PRAIRIE POTHOLE REGION OF NORTH DAKOTA

Baxter E. Vieux[1]*, Gary E. Freeman[2], Erwan LeDimet[1] and Sylvain Guinepain[1]
[1]*Environmental Modeling and GIS Laboratory, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK 73019;* [2]*Hydraulics Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS 39180*

INTRODUCTION

The objective of this project was to model the hydrologic transport of sediment in complex terrain in the Prairie Pothole Region (PPR) of North Dakota. The National Biological Service together with the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers, Waterways Experiment Station have undertaken the assessment of farming practices on accelerated erosion and sedimentation rates in the wetlands of this region. Various farming and land management practices with the drainage area draining to wetlands affect the rate at which soil is detached by raindrop impact and transported by the runoff. Tillage practices tend to conserve or destroy crop residues which protect soil from erosion. Depending on the application of conservation practices such as terraces, contour farming and crop residue management, erosion and sedimentation rates may be accelerated or reduced in the closed watersheds that drain to the wetlands.

Data have been collected to assess the different rates of sediment deposition resulting from drainage areas consisting of native prairie, Conservation Reserve Program land (CRP), buffered wetlands, and tilled watersheds. Characteristics of the sediment, statistical analysis of the sediment for 1993, and other data reported by the U.S. Environmental Protection Agency (EPA) (1) indicate that wetlands with drainage areas consisting of tilled cropland have a greater sediment deposition than CRP cropland.

APPROACHES TO SEDIMENT TRANSPORT SIMULATION

Transport of sediment is affected by the detachment of soil particles by raindrop impact and transport by the runoff, susceptibility of the soil to detachment, the presence of material such as crop residue that reduces the magnitude of eroding forces, and management of the soil such that it is less susceptible to erosion. The rate at which sediment may be carried by the runoff is termed the capacity-limited transport rate. The rate at which sediment becomes available for transport is the supply-limited transport rate. At a given location on a slope, if the amount of sediment made available for transport by rainfall detachment is less than the transport capacity, then the sediment load moving down slope will be limited by the supply of sediment. If, on the other hand, the available sediment by detachment is greater than the transport capacity, then the sediment load is limited by the transport capacity (2, 3). The following factors affect the capacity- and supply-limited transport rates.

Rainfall and Runoff

Rainfall and runoff provide the basic driving energy for the erosion and transport processes. In stream channels where the bulk of sediment transport relationships have been developed, particles are continuously exchanged between the bed and the flow. In upland erosion, this does not usually occur because the shear required to detach the particle is much more than that required for transport. Foster and Huggins (4) reported that the critical shear stress required to detach soil particles is around 2.9 N/m^2 whereas transport only requires around 0.5 N/m^2 for a sand of 342 μm. Rainfall impact on the soil surface is necessary for the detachment of particles, and, therefore, the supply of sediment. Modeling of upland erosion requires the simulation of supply rates and transport to obtain an estimate of sediment transport at a particular location in the landscape.

Topography

Topography affects the rate of runoff through slope and the length of slope. As slope increases so does the transport capacity. As length increases at a given slope, more drainage area contributes more runoff volume and rates providing more transport capacity. As soil particles are detached in the upper reaches of the watershed and transported down slope to the wetlands, the relative magnitudes of supply and transport rates govern the amount of sediment transported. Slope of the landsurface plays a key role in this sub-process. As slope decreases closer to the wetlands, it is expected that the transport capacity will fall below the supply rate. In the near-wetland part of the landscape, deposition has been observed and is explained by the decrease in transport capacity due to flatter slopes.

Soils

Soils have different susceptibilities to erosion forces. Thus, soil type and the management of the soil influences the rate at which soil may be detached by rainfall impact (5). Soil transportability is the ease with which the detached soil particles are transported by the water. Soil is eroded as primary particles (e.g., sand, silt, and clay) or as aggregates of different particle sizes and organic matter. Continual, intensive tillage breaks down the soil structure and depletes organic matter enhancing erodibility. Sediment produced on uplands as opposed to sediment flowing in rivers is a mixture of primary particles and aggregates (6). The proportion of primary particles and aggregates depends on upslope sorting, soil properties, and the amounts coming from rill and interrill areas. Soil particle sizes affect transport and deposition rates. Clays, if they are primary particles, may never be deposited due to resuspension caused by turbulence; whereas silts and sands are the first to be deposited as transport capacity decreases below the supply rate.

Cover

Cover, including plant canopy, mulches, plant residue, or densely growing plants, has a greater influence on erosion than any other factor. Cover, in contact with the soil, greatly reduces rill erosion by cushioning raindrop impact and reducing the shear stress exerted by flowing water. Strips of dense mulches or grasses can induce deposition and filter sediment from the runoff. Tillage type, frequency, and elapsed time between tillage and a runoff event affect the detachment of soil particles.

Given these factors that affect the detachment of soil particles (supply) and transport of sediment, the overall goal of simulation is not only to adequately represent the processes but to provide realistic estimates of the impacts of anthropogenic effects on wetlands. We were interested in both the capacity and the supply-limited rates because as runoff from the watershed divide traverses the topography, either control may dominate the transport of sediment. From preliminary analysis of sediment taken from the wetlands, CRP treated watersheds yield less sediment than those that were tilled (1). This indicates that the rate of sediment deposition is dependent on the supply which in turn is affected by tillage and land management practices.

SUPPLY LIMITED SEDIMENT TRANSPORT

Kilinc described a formula that includes the effects of slope and runoff on sediment transport (7). This equation was modified by Julien (8) to account for the soil erodibility, cropping and tillage effects, and conservation practices. The mass transport rate in metric tons per second per meter of width, q_t, is

$$q_t = 2.5x10^4 S_o^{1.66} q^{2.035} \quad (1)$$

where, q_t is the mass transport rate in metric tons per meter of width and seconds; S_o is the land surface slope; and q is the unit width flow rate in m^2/s. This equation can be further modified (8) to account for the soil erodibility, cropping and tillage effects, and conservation practices as follows

$$q_t = 1.7x10^5 S_o^{1.66} q^{2.035} KCP \quad (2)$$

where, K is the soil erodibility, C is the crop management factor, and P is the conservation practice factor. The factors K, C, and P are readily available for specific soils, crop management, and conservation practices. Further, K, C, and P represent the supply-limiting characteristics of the watershed.

CAPACITY LIMITED SEDIMENT TRANSPORT

When sediment transport is controlled by the capacity of the flow, there exist several equations for predicting the transport capacity. Total load formulas applicable to upland erosion conditions include the formulas of Ackers and White (9), Foster (2), Yang (10), Laursen (11), and Einstein (12). Bed load formulas include Meyer-Peter and Muller (13), Bagnold (14), and Yalin (15). Alonso et al. (16) compared these formulas against field and laboratory experiments concluding that no formula satisfactorily represented the spectrum of sediment transport conditions or characteristics. Further, it was observed that equation by Yang (10) best estimated streamflow carrying fine to coarse sands; and that the Yalin (15) equation is best suited to overland flow, particularly on concave slopes.

Foster and Meyer (17) compared the sediment transport predicted by the Yalin equation to laboratory and erosion plot studies and found excellent agreement. Erosion of natural agricultural soils has been observed to occur by detachment and saltation of soil aggregates due to lifting forces induced by the flowing water. The Yalin equation assumes that sediment motion begins when the lift force of flow exceeds a critical lift force. The particle is transported downstream until the particle weight forces it out of the flow and back in the bed. The number of particles in motion at a given time is a linear function of an excess shear parameter, δ. The required hydrodynamic parameters are energy slope, S_f and the hydraulic radius, R. The transportability of the soil is determined by the particle (aggregate or primary) specific gravity, the diameter, and the critical lift force, Y_{cr}, given by the Shields diagram which defines incipient motion based on particle and fluid characteristics. The Yalin equation defines a dimensionless transport rate, Π (equation 3), in which W_s is transport rate in Newtons per second per unit width; SG is the specific gravity; ρ_w is the mass density of the water; d is the diameter in meters; g is the acceleration of gravity in m/s^2; the shear velocity; V_* is as in equation 4;

$$\Pi = \frac{W_s}{SG \rho_w \, d \, V_* \, g} = 0.635\ \delta\left(1 - \frac{1}{\sigma}Ln(1+\sigma)\right) \quad (3)$$

$$V_* = \sqrt{g\,R\,S_f} \quad (4)$$

The excess shear parameter, δ in equation (3) is

$$\delta = \frac{Y}{Y_{cr}} - 1 \quad \textit{if } Y > Y_{cr} \textit{ else } 0 \quad (5)$$

where the lift force, Y is

$$Y = \frac{V_*^2}{(SG-1)\,g\,d} \quad (6)$$

The critical lift force Y_{cr} is defined as a function of a dimensionless particle diameter, D_*

$$D_* = d\left(\frac{(SG-1)\,g}{\nu_m^2}\right)^{1/3} \quad (7)$$

The Shields diagram, usually presented in graphical form, may be expressed as a piece-wise continuous set of functions:

(8)

<	D*	=4	Ycr	=	$0.24{*}D_*^{-1}$
4<	D*	<=10	Ycr	=	$0.14{*}D_*^{-0.64}$
10<	D*	<=20	Ycr	=	$0.04{*}D_*^{-1.0}$
20<	D*	<=150	Ycr	=	$0.013{*}D_*^{-0.29}$
150>	D*		Ycr	=	0.055

In equation (3) the value of $\sigma = A * \delta$ where A is

$$A = 2.45\ (SG)^{-0.4}\ Y_{cr}^{0.5} \quad (9)$$

This defines each of the terms in equation 3. The resulting value of Π is dimensionless, whereas, the value of W_s computed with parameters in the Meters-Kilogram system, yields the capacity-limited transport rate in units of Newtons per second per unit width [N/(m•s)].

SIMULATION OF SEDIMENT TRANSPORT IN THE PRAIRIE POTHOLE REGION

We applied the principles outlined above to sediment transport in wetland drainage areas in the PPR study area. Specific characteristics of sediment and topography in this region are important in the selection of appropriate transport equations and the correct application. Further, the overall goals of the project must be recognized so that model results are useful to decision makers.

COUPLED HYDRODYNAMICS AND SEDIMENT TRANSPORT

The complex terrain associated with the PPR must be adequately represented so that the simulated flow depths, velocities, and unit flow rate are predicted. The hydrodynamic module produces flow depth and velocities which are used to compute the unit flow rate, q. This flow rate was then used to compute transport rates and load.

SEDIMENT CHARACTERISTICS

The sediment characteristics in relation to the hydraulic regime was important in characterizing the type of sediment transport mechanisms. The sediment particle size distribution gives an indication of the potential sizes of sediment transported. The term potential was used since it is unknown whether the soil particles were transported as primary particles or aggregates or a combination. However, it was instructive to consider what the sediment size ranges are and the influence this has over the transport mechanisms. Sediment analyses taken from EPA (1) indicate that the sediment sizes, using logarithmic interpolation for the d_{50} , range from 15 μm to 73 μm. Figures 1 shows the ranges of particle sizes for selected potholes near Woodworth, North Dakota. The d_{50} for the W13E1 pothole was taken as 33 to 50 μm. This places the median grain size in the range of a coarse silt (31 to 61 μm).

Figure 1. Particle size distributions for potholes: 7-24, 7-32, 22-24, W13E-1, and W13E-2.

HYDRODYNAMIC SIMULATION

The hydrodynamic simulation was performed for a segment taken from the Digital Elevation Model (DEM) for the W13E1 pothole. The slope in this segment was 2% over a length of 80 meters. The rainfall intensity was taken at the higher end of the expected rainfall intensities, 18.97 cm/hr lasting for the duration of 360 seconds. The hydrodynamic module simulates flow depth and velocities for maps of topography (DEM), hydraulic roughness, and applied rainfall intensities.

SEDIMENT TRANSPORT RATES

Supply-Limited Transport

To illustrate the transport computations for the W13E1 watershed, assumed conditions with respect to the supply-limited conditions (parameters K, C, and P) are made. Two conditions were modeled for CRP and tilled treatments with the following parameters. The resulting sediment transport is supply-limited and was the maximum amount that could be transported from the drainage area.

$So=$	0.02	
$K=$	0.42	Silt Loam with 2% OM
$C_{CRP}=$	0.24	No canopy and 20% cover by undecayed residues.
$C_{tilled}=$	0.45	No canopy and 0% cover by undecayed residues.
$P_{CRP}=$	0.5	Farming on contour
$P_{tilled}=$	1	No conservation practices.

The parameters chosen are typical values but should be modified for each soil mapping unit, land use/management, and cropping plan in each drainage area.

CAPACITY-LIMITED TRANSPORT

The Yalin equation defines the sediment transport limited by the capacity of the flow. This equation is independent of sediment source, and as such, simply represents the capacity of the flow to carry a particular sediment size. Natural sediments are comprised of a range of sizes. Capacity-limited transport equations often over-predict the total sediment load when applied to sediment size fractions and then summed by the percentage represented by each size. Thus, the Yalin equation was applied to the median grain size to compute the sediment load. The constants used to compute the sediment transport rate using equation 3 ff were:

Constants:

$g=$	9.80	m/s^2
υ_m	8.94e-07	m^2/s
$\rho_w=$	1000.00	kg/m^3
$\gamma=$	9800	N/m^3

Sediment Characteristics:

d_50=	3.30e-05 m
Sg=	2.65
D*=	0.90
Ycr=	0.27
A=	0.86

The time-dependent supply-limited transport rate is shown in Figure 2 with the time-dependent capacity-limited transport rate. Note that the capacity-limited transport rate is less than both the CRP and tilled treatment transport rates. This indicates that the capacity-limited transport rate governs. The estimated transport rate is, therefore, the lesser of the two (capacity versus supply); the capacity-limited transport rate. Meyer and Wischmeier (3) found from erosion plot studies that for slopes of less than 3%, transport capacity was the limiting rate. The segment modeled in this example has an average slope of 2%.

CONCLUSIONS

The sediment transport associated with upland erosion is controlled by either the supply-limited or the capacity-limited transport rate. Depending on storm characteristics, topography, soils, land use, and management, either rate may dominate. The supply of sediment may be limited by crop residue which reduces soil detachment by rainfall. As the detached sediment becomes entrained in the runoff, it is transported as suspended or bed load depending on flow depth, velocity, and soil particle/aggregate size and specific gravity.

Under the conditions analyzed for the W13E1 pothole, both supply-limited and capacity-limited transport may dominate the sediment transport rate. Particularly on flat slopes encountered near the emergent vegetation of the wetland, sediment begins to drop out due to reduced transport capacity. The supply of sediment is also affected by the land treatment. CRP treated watersheds show less sediment transport than tillage without conservation treatment. Supply-limited transport rates for CRP conditions are 33% of the tilled conditions shown in Figure 2. The capacity-limited rate using the Yalin equation shows that it is controlling at all times during the storm for the flow rates encountered at 75 meters downslope from the watershed divide. Further analysis is needed to determine if this is true along the land surface profile from the watershed divide to the edge of the wetland.

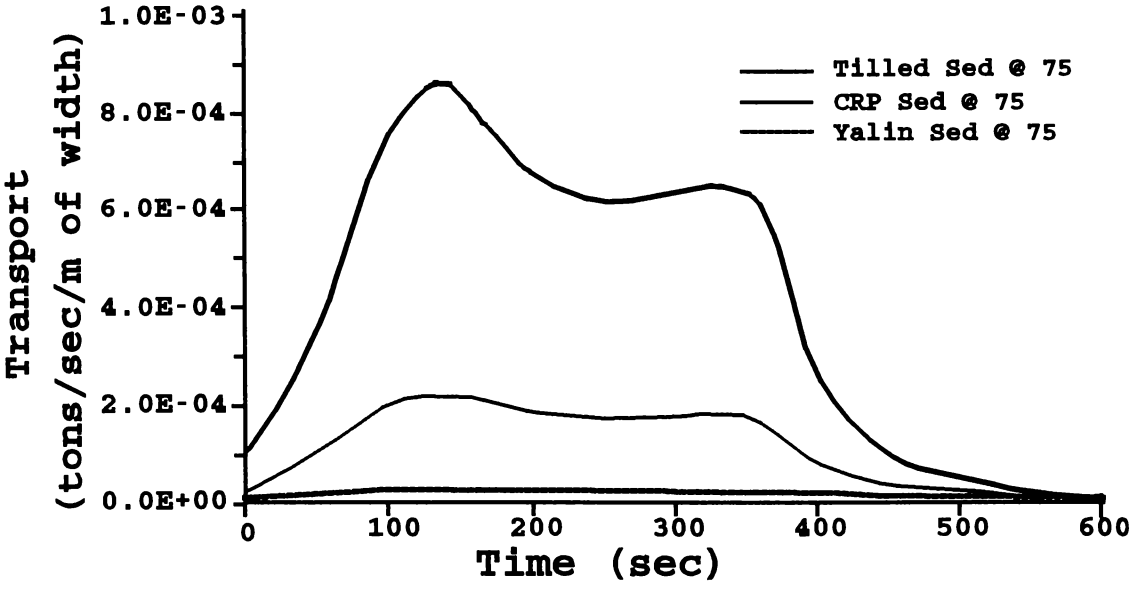


Figure 2. Time-dependent supply-limited and capacity-limited sediment transport rates @ 75 meters, pothole W13E-1.

Acknowledgments--Permission has been granted by the Chief of Engineers to publish this research. Funding has been provided to the University of Oklahoma by the U.S. Army Corps of Engineers Waterways Experiment Station under contract DACA39-94-K-0026. Funding for the Waterways Experiment Station work was provided by the Duluth Research Laboratory of the U.S. Environmental Protection Agency, Office of Research and Development under an interagency agreement titled "Prairie Pothole Sedimentation Model Development," number DW21936868-01-2. The use of trademarked or commercial names in no way implies endorsement of the product by the U.S. Government, the U.S. Army Corps of Engineers, the U.S. Army Engineer Waterways Experiment Station, or the Environmental Protection Agency.

1. EPA (1995) 1993 Sediment trap data update. Unpublished report, EPA--Environmental Research Laboratory, Duluth, MN.

2. Foster, G. R. (1982) Modeling the Erosion Process *in* Hydrologic Modeling of Small Watersheds, eds. C. T. Haan, H. P. Johnson, D. L. Brakensiek, ASAE Monog. No. 5, St. Joseph, MI.

3. Meyer, L. D. and Wischmeier, W. H. (1969) Mathematical simulation of the process of soil erosion by water. Trans. ASAE 12,754-758, 762.

4. Foster, G. R. and Huggins, L. F. (1977) Deposition of sediment by overland flow on concave slopes *in* Soil Erosion Prediction and Control. Special Publ. No. 21. Soil Conserv. Soc. Am., Ankeny, IA.

5. Wischmeier, W. H. and Mannering, J. V. (1969) Relation of soil properties to its erodibility. Soil Sci. Soc. Am. Proc. 33,131-137.

6. Meyer, L. D., Foster, G. R. and Romkens, M. J. M. (1975) Source of soil eroded by water from upland slopes. *in* Present and Prospective Technology for Predicting Sediment Yields and Sources. ARS-S-40, USDA-ARS.

7. Kilinc, M. Y. (1972) Mechanics of soil erosion from overland flow generated by simulated rainfall. Ph.D. Dissertation, Colorado State University, Fort Collins.

8. Julien, P. Y. (1995) Erosion and Sedimentation, Cambridge University Press, NY.

9. Ackers, P. and White, W. R. (1973) Sediment Transport: New approach and analysis. J. Hyd. Div. ASCE 99, no. HY11,2041-60.

10. Yang, C. T. (1973) Incipient motion and sediment transport. J. Hyd. Div. ASCE, 99, no HY10,1679-1704.

11. Laursen, E. (1958) The total sediment load of streams. J. Hyd. Div. ASCE, 54, HY1, 1530-66.

12. Einstein, H. A. (1950) The bed load function for sediment transportation in open channel flows. Tech. Bull. No. 1026, USDA-SCS.

13. Meyer-Peter, E. and Muller, R. (1948) Formulas for bed load transport. Proc. 2nd Meeting IAHR, Stockholm.

14. Bagnold, R. A. (1956) The flow of cohesionless grains in fluids. Philosophical Trans. Royal Soc. London, Series A 249,235-297.

15. Yalin, M. S. (1977) Mechanics of sediment transport, 2nd edition. London, Pergamon Press.

16. Alonso, C. V., Neibling, W. H. and Foster, G. R. (1981) Estimating sediment transport capacity in watershed modeling. Trans. ASAE 24 (5),1211-1220.

17. Foster, G. R. and Meyer, L. D. (1972) Transport of soil particles by shallow flow. Trans. ASAE 15,99-102.

UPLAND VEGETATION AT THE WOODWORTH STUDY AREA

Mavis I. Meyer*
U.S. Fish and Wildlife Service
Denver Federal Center
Denver, CO 80225

Upland habitats on the Woodworth Study Area (WSA) are mostly croplands, seeded grasslands, and native grasslands. The croplands undergo annual tillage, seeded grasslands are fields planted with a mixture of perennial grasses and legumes, and the native grasslands have no history of tillage. Shelterbelts, roads, and an abandoned gravel pit area make up the remainder of the uplands.

The long range plan for managing the upland vegetation was to develop seeded cover attractive to nesting waterfowl, to restore native grass stands, and to maintain existing native prairie (1). By 1970, more than 500 acres of former cropland were seeded into mostly non-native cool-season grasses and legumes. The primary grass species were intermediate wheatgrass (*Agropyron intermedium*), tall wheatgrass (*A. elongatum*) and slender wheatgrass (*A. caninum*), and the legumes were alfalfa (*Medicago sativa*) and yellow sweetclover (*Melilotus officinalis*). Two fields were seeded into basin wild rye (*Elymus cinereus*). The WSA provided the landbase to experiment with native grass seedings during the mid 1970's. About 15% of the area was seeded with native grasses by 1980. The principal cool-season species were green needlegrass (*Stipa viridula*) and western wheatgrass (*Agropyron smithii*). Some fields were over-seeded with warm season species including switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardi*), and Indian grass (*Sorghastrum nutans*).

Cattle grazing, prescribed burning, and non-use were used to manage the existing native prairie. Several permanently marked vegetation transects were established, along which data on visual obstruction, canopy cover, and plant species composition were collected. The transects were monitored annually from 1975-1985 to evaluate treatment effects on nesting cover. Permanent photo stations and other visual observations provided supplemental information.

The native prairie is divided into five classes: mixed grass, shrub, tall grass, broad-leaved forb and tree (2). The mixed grass is dominated by blue grama (*Bouteloua gracilis*), native mixed grass (*Bouteloua gracilis, Stipa comata*), and Kentucky bluegrass (*Poa pratensis*) communities. The shrub class is divided into two communities, low shrub dominated by wolfberry (*Symphoricarpos occidentalis*), and tall shrub dominated by chokecherry (*Prunus virginiana*). Tall grass communities are dominated by little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon gerardi*), indian-grass (*Sorghastrum nutans*), and prairie cordgrass (*Spartina pectinata*). The brood-leaved forb community is primarily maximilian sunflower (*Helianthus maximiliani*) and Canada goldenrod (*Solidago canadensis*). Native trees, cottonwood (*Populus deltoides*) and willow (*Salix* spp.) occur in the gravel pit area.

The WSA is located in a vegetation transitional zone where the taller grasses of the drift plain intermingle with mixed and short grasses of Missouri Coteau. The mosaic of different soils and moisture regimes provide the foundation for over 280 upland plant species. Although the WSA is small, it remains a critical research area for natural resource interests.

---

1. Higgins, K. F., Kirsch, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl Production on the Woodworth Station in South-central North Dakota, 1965-1981. U.S. Fish Wildl. Serv. Resour. Publ. 180.

2. Meyer, M. I. (1985) Classification of native vegetation at the Woodworth Station, North Dakota. Prairie Nat. 17,167-175.

TERRESTRIAL BIRD COMMUNITIES ON THE WOODWORTH STUDY AREA

Douglas H. Johnson*
National Biological Service
Northern Prairie Science Center
8711 37th Street Southeast
Jamestown, ND 58401

INTRODUCTION

The mixed-grass prairie is one of the largest ecosystems in North America, with significant areas preserved for natural values in national wildlife refuges, waterfowl production areas, state game management areas, and nature preserves. Mixed-grass prairie evolved with fire, and fire is frequently used by managers to maintain the habitat. Despite the importance of the mixed-grass prairie to numerous species of birds, and the aggressive management applied to many sites, relatively little is known about the effects of fire on the suitability of the habitat for breeding birds. I conducted studies at the Woodworth Study Area (WSA) to determine the effects of prescribed burning on populations of grassland birds. Details of the results of that analysis are presented in (1); the present paper summarizes the key findings and also presents a more complete listing of the birds encountered.

STUDY AREAS

Study plots were located in relatively homogeneous areas within seven different quarter-sections, the units that received various treatments under management at the WSA. Plots were situated to avoid large wetlands, in order to concentrate on upland bird communities. Six of the plots were subjected to burning under different regimes; the remaining plot served as a control. The seven study plots are denoted by the quarter-section in which they were located. Plot 13 served as a control, with no treatment applied to it. It had been grazed during 1906-61, but has been left idle subsequently. Originally 8.09 ha in size, it was increased to 10.12 ha in 1973. All or portions of eight seasonal and two temporary wetland basins lie within the plot, totalling about 1.2 ha. Common plant species in the uplands are Kentucky bluegrass (*Poa pratensis*), needle-and-thread (*Stipa comata*), stiff sunflower (*Helianthus rigidus*), and Canada goldenrod (*Solidago canadensis*). Wolfberry (*Symphoricarpos occidentalis*), silverberry (*Eleagnus commutata*), and Woods' rose (*Rosa woodsii*) form shrubby patches of various size. One thicket of chokecherry (*Prunus virginiana*), surrounded by wolfberry and silverberry, has become decadent during the years of the surveys.

Plot 2, 8.68 ha in size, was surveyed only during 1977-82, after which the trail to it became difficult to navigate. It had been grazed or hayed during 1906-67, then left idle except for five prescribed burns. It contains all or portions of seven seasonal wetlands, about 0.9 ha in total. Kentucky bluegrass is abundant, and needle-and-thread, yarrow (*Achillea lanulosa*), fringed sage (*Artemisia frigida*), and prairie wild rose (*Rosa arkansana*) are common. Stands of wolfberry and silverberry also occur.

Plot 7, 6.07 ha in extent, was hayed during 1904-55. It had been plowed in 1956 for one year of crop production. Alfalfa (*Medicago sativa*) and possibly some tame grasses were planted in 1958, after which it was grazed or hayed until 1970. It has since been subjected to four prescribed burns. Six seasonal and two temporary wetlands, covering 1.1 ha, are included in the plot. Dominant upland plants are needle-and-thread, green needlegrass (*Stipa viridula*), alfalfa, Kentucky bluegrass, rigid goldenrod (*Solidago rigida*), and stiff sunflower. Patches of silverberry and wolfberry have increased during the study.

Plot 9 is also 6.07 ha. It consists of unbroken sod that had been hayed and probably grazed during 1908-65. It has been burned five times since then. Two small seasonal and one ephemeral wetland cover 0.2 ha. Dominant plant species are Kentucky bluegrass, needle-and-thread, yellow sweetclover (*Melilotus officinalis*), white prairie aster (*Aster ericoides*), and stiff sunflower. Wolfberry occurs in several patches.

Plot 11, 4.86 ha in size, had been cropped during 1917-27 and from 1934 to about 1940. It then reverted to grass and was grazed through 1970. Since then, it has been burned four times. It contains one ephemeral and portions of two seasonal wetlands, totalling about 0.5 ha. The uplands are dominated by Kentucky bluegrass and, to a lesser extent, smooth brome (*Bromus inermis*).

Plot 16 is 6.07 ha in size. It was grazed from 1906 to 1968, after which it was treated with a total of six prescribed fires. Five seasonal wetlands and small portions of two seasonal to semipermanent wetlands lie within the plot, with a total area of about 0.6 ha. Common plants are Kentucky bluegrass, quackgrass (*Agropyron repens*), needle-and-thread, and little bluestem (*Andropogon scoparius*), as well as wolfberry and silverberry.

Plot 18, also 6.07 ha in size, is unbroken prairie sod that had been grazed from 1906 to 1968. The plot was burned seven times between 1969 and 1990. In addition, it was intensively grazed by sheep during 1973 and 1974. The plot contains four small wetlands--one ephemeral, two temporary, and one seasonal--covering <0.1 ha. At the beginning of the surveys, the plot had several thickets of chokecherry and hawthorn (*Crataegus chrysocarpa*). The various treatments, as well as nest-searching with a cable-chain device, have reduced the thickets considerably. Other common plants include Kentucky bluegrass, blue grama (*Bouteloua gracilis*), and fringed sage.

Plots were measured and marked by use of compass and pacing. Surveyor's flags were placed at 40-m intervals on a grid throughout each plot to facilitate recording of bird locations.

FIELD METHODS

Each year during 1972-95 (1977-82 for Plot 2) the breeding bird community of each plot was estimated by conducting several surveys and mapping territories. Standard methods (2, 3) were used, and annual reports were submitted for publication in *American Birds* or the *Journal of Field Ornithology* (Appendix 1). About eight visits were made to each plot during late May through mid June each year. Surveys were done from just before dawn to late morning. Early-morning surveys emphasized concurrent registrations of indicated pairs of the same species, in order to define multiple territories. Surveys later in the morning, when vocalizations were reduced, focused on reflushing birds to delineate their territories (4).

In most years, one other observer and I conducted independent surveys and subsequently compared results. For consistency, I personally estimated the number of territories from the locations plotted on field maps.

RESULTS

The species observed during these censuses and total numbers are given in Table 1. More detailed analyses (1) were conducted on 17 of the most common terrestrial species. The birds considered in these analyses can be grouped into three major categories, depending on their response to burning and successional changes in vegetation. In the first group are those species that respond positively and immediately to a burned area. Included are three of the common shorebirds at Woodworth: killdeer, marbled godwit, and upland sandpiper. All three favor open areas with sparse vegetation, where they forage. The killdeer and marbled godwit likewise nest in these open areas, but the upland sandpiper typically nests in heavier vegetation. Other species, not treated here in because of limited numbers observed, that likely would favor recently burned mixed-grass prairies include the horned lark and vesper sparrow.

Table 1. Total numbers and average density (per 100 ha) of indicated pairs of birds recorded in censuses at Woodworth Study Area, North Dakota. (Common names follow American Ornithologists' Union 1983.)

Species	Total count	Average density
Clay-colored sparrow	275.5	28.32
Red-winged blackbird	199.2	20.48
Bobolink	158.2	16.26
Blue-winged teal	158.0	16.24
Brown-headed cowbird	133.1	13.68
Grasshopper sparrow	115.1	11.83
Western meadowlark	110.7	11.38
Common yellowthroat	77.6	7.98
Eastern kingbird	76.1	7.82
American coot	62.2	6.39
Gadwall	44.5	4.57
Willow flycatcher	35.6	3.66
Savannah sparrow	34.0	3.49
Mallard	31.6	3.25
Northern shoveler	28.9	2.97
Yellow warbler	28.9	2.97
Upland sandpiper	25.2	2.59
Sedge wren	19.8	2.04
Killdeer	17.6	1.81
American goldfinch	13.2	1.36
Common snipe	12.1	1.24
Northern pintail	10.1	1.04
Western kingbird	9.0	0.93
Gray catbird	8.5	0.87
Barn swallow	8.3	0.85
Marbled godwit	7.9	0.81
Willet	7.9	0.81
Sora	7.0	0.72

Table 1. (continued).

Species	Total count	Average density
Baird's sparrow	6.7	0.69
Common grackle	6.1	0.63
Song sparrow	5.6	0.58
Yellow-headed blackbird	5.4	0.56
Black tern	4.8	0.49
Sharp-tailed grouse	4.7	0.48
Lesser scaup	4.6	0.47
Brown thrasher	4.3	0.44
Mourning dove	3.9	0.40
Redhead	3.7	0.38
Ruddy duck	3.3	0.34
Chestnut-collared longspur	2.8	0.29
Common nighthawk	2.6	0.27
Cliff swallow	2.3	0.24
Green-winged teal	2.3	0.24
Horned lark	2.3	0.24
Northern harrier	2.2	0.23
Vesper sparrow	2.1	0.22
American bittern	1.8	0.18
Le Conte's sparrow	1.6	0.16
American wigeon	1.2	0.12
Wilson's phalarope	1.2	0.12
Bank swallow	1.2	0.12
Ring-necked pheasant	1.1	0.11
Pied-billed grebe	1.1	0.11
Black-billed cuckoo	0.9	0.09
Tree swallow	0.9	0.09
Gray partridge	0.7	0.07
Lark bunting	0.7	0.07
Swainson's hawk	0.7	0.07
Marsh wren	0.5	0.05
Orchard oriole	0.5	0.05
Common flicker	0.4	0.04
Canada goose	0.3	0.03
Ferruginous hawk	0.3	0.03
Northern oriole	0.3	0.03
Red-tailed hawk	0.3	0.03
Ring-billed gull	0.3	0.03
Sharp-tailed sparrow	0.3	0.03
Short-eared owl	0.3	0.03
Black-crowned night-heron	0.2	0.02
Cedar waxwing	0.2	0.02
Dickcissel	0.2	0.02
Long-eared owl	0.2	0.02
American robin	0.1	0.01
Brewer's blackbird	0.1	0.01
Canvasback	0.1	0.01
Cooper's hawk	0.1	0.01
House wren	0.1	0.01
Least flycatcher	0.1	0.01
Loggerhead shrike	0.1	0.01
Ring-necked duck	0.1	0.01

The second category includes those species that use habitats enhanced by long-term protection from fire, specifically the woody vegetation that encroaches in unburned grassland. The most common species at Woodworth in this category are eastern kingbird, willow flycatcher, yellow warbler, common yellowthroat, clay-colored sparrow, and brown-headed cowbird. The red-winged blackbird also uses brushy vegetation, but at Woodworth relied more on wetland habitats.

In the third category are birds that avoid recently burned areas, but favor grassland with little or no woody vegetation. Several of these species are most common two to five years following a fire. These might be termed true grassland species. Included in this category are bobolink, western meadowlark, grasshopper sparrow, Baird's sparrow, and savannah sparrow.

Two species analyzed here did not fit neatly into any of the categories. The willet, although commonly seen in the uplands, uses mostly wetland habitat except for nesting. No evidence of a response to burning was detected. The sedge wren used upland habitats at Woodworth, but did so most often when long-term precipitation patterns resulted in luxuriant herbaceous growth. That species showed no response to grassland burning, except for a reduction immediately following a fire.

CONCLUSIONS

Management of mixed-grass prairies should emphasize those species of birds that require that type of habitat; these are the true grassland birds, many of which have suffered population declines during the past quarter-century. Maintaining populations of those species on mixed-grass prairie will be facilitated by a regime of prescribed burning.

Acknowledgments--Establishment and maintenance of the plots was done by L. M. Kirsch (deceased), H. W. Miller, K. F. Higgins, J. M. Callow, and H. L. Clark, to whom I am most grateful. R. E. Stewart (deceased) and R. L. Kologiski (deceased) surveyed the vegetation in the plots. Other bird observers were P. F. Springer (1972), G. L. Krapu (1973), J. M. Callow (1979-80), C. A. Faanes (1981-83, 1987), J. M. Andrew (1981), J. L. Eldridge (1984), J. Hassler (1985), K. A. Luttschwager (1985), T. M. Pabian (1985), J. M. Hicks (1986), and M. D. Schwartz (1987-89, 1991-95).

1. Johnson, D. H. (1996) Effects of fire on bird populations in mixed-grass prairie, in Ecology of Great Plains vertebrates and their habitats. (Knopf, F. L. and Samson, F. B., eds). In press.

2. Hall, G. A. (1964) Breeding-bird censuses: why and how. Audubon Field Notes 18,413-416.

3. Van Velzen, W. T. (1972) Breeding bird census instructions. Am. Birds 26,1007-1010.

4. Wiens, J. A. (1969) An approach to the study of ecological relationships among grassland birds. Ornithol. Monogr. 8.

Appendix 1. Citations of published censuses of birds on Woodworth Study Area.

Johnson, D. H. and Springer, P. F. (1972) Breeding bird populations of selected grasslands in east-central North Dakota. Am. Birds 26,970-975.

Johnson, D. H. and Krapu, G. L. (1973) Thirty-seventh breeding bird census - mixed prairie. Am. Birds 27,989-990.

Johnson, D. H. (1974) Breeding bird populations of selected grasslands in each central North Dakota--1974. Am. Birds 28,1030-1031.

Johnson, D. H. (1975) Breeding bird populations of selected grasslands in each central North Dakota--1975. Am. Birds 29,1119-1120.

Johnson, D. H. (1977) Breeding bird populations of selected grasslands in each central North Dakota--1976. Am. Birds 31,62-63.

Johnson, D. H. (1978) Breeding bird populations of selected grasslands in each central North Dakota--1977. Am. Birds 32,81-82.

Johnson, D. H. (1979) Forty-second breeding bird census - mixed prairie. Am. Birds 33,80.

Johnson, D. H. and Callow, J. M. (1980) Forty-third breeding bird census. On selected prairies in each-central North Dakota--1979. Am. Birds 34,67-69.

Johnson, D. H. and Callow, J. M. (1981) Forty-fourth breeding bird census. On selected prairies in east-central North Dakota - 1980. Am. Birds 35,78-79.

Johnson, D. H., Faanes, C. A. and Andrew, J. M. (1982) Forty-fifth breeding bird census - Mixed prairie. Am. Birds 36,79-80.

Johnson, D. H. and Faanes, C. A. (1983) Thirty-fifth breeding bird census - mixed prairie. Am. Birds 37,80, 82-83.

Faanes, C. A. and Johnson, D. H. (1984) Forty-seventh breeding bird census - Kentucky blue grass prairie and mixed prairie I-VIII. Am. Birds 38,96-97.

Johnson, D. H. (1989) Bird Censuses - Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 60(supplement),58-60.

Johnson, D. H. and Schwartz, M. D. (1990) Bird Censuses 77-82: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 61(supplement),73-75.

Johnson, D. H. and Schwartz, M. D. (1991) Bird Censuses 86-91: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 62(supplement),82-84.

Johnson, D. H. and Schwartz, M. D. (1992) Bird Censuses 115-120: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 63(supplement),105-106.

Johnson, D. H. and Schwartz, M. D. (1993) Bird Censuses 116-121: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 64(supplement),105-107.

Johnson, D. H. and Schwartz, M. D. (1994) Bird Censuses 126-131: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 65(supplement),120-122.

Johnson, D. H. and Schwartz, M. D. (1995) Bird Censuses 123-128: Kentucky bluegrass prairie and mixed prairies I-V. J. Field Ornithol. 66(supplement),109-11.

WATERFOWL STUDIES AT THE WOODWORTH STUDY AREA, STUTSMAN COUNTY, NORTH DAKOTA: 1965-1995

Kenneth F. Higgins[1]* and Robert O. Woodward[2]
National Biological Service
[1]South Dakota Cooperative Fish and Wildlife Research Unit, Brookings, SD 57007 and [2]Northern Prairie Science Center, 8711 37th Street Southeast, Jamestown, ND 58401

The Woodworth Study Area (WSA) of the Northern Prairie Science Center (NPSC) is a waterfowl production area dedicated to research. Field investigations on WSA began in April 1963 and continue until present. From 1964 through 1968, land-use treatments on the WSA were maintained similar to those of prior years when the land was in private ownership. Since 1969, the WSA has been used for studying the response of wildlife to applied treatments of grazing, burning, idling, and annual cropping.

The primary waterfowl studies at the WSA were designed to address wildlife responses to land management practices (1) and to evaluate their relevance to past and future management of public and private lands, but with emphasis on those lands dedicated to wildlife production. Seventeen years (1965-1981) of waterfowl studies at the WSA were described in detail by Higgins et al. (2). During these years waterfowl use of and production from various habitats were assessed by monitoring duck breeding pairs and broods on wetlands and by conducting nesting studies in upland grassland types. Waterfowl monitoring and research studies were continued until 1988, but at a less intense scale after 1985. From 1988 until the present, studies on the WSA have been more broadly ecological, with less emphasis on waterfowl. During the past 3 decades, activities at the WSA can be partitioned into 3 distinct phases: The Initial Years, The Habitat Manipulation Years, and The Recent Years.

THE INITIAL YEARS

We recognize 1963-1968 as the initial years for waterfowl work at the WSA. Land management during this period was maintained similar to that in place before federal acquisition of much of the WSA lands. During this period the study area was mapped and characterized, techniques for counting and monitoring waterfowl were developed and evaluated (2, 3), and methods of conducting large-scale waterfowl nesting studies were developed and implemented (4, 5, 6).

The staff of the WSA also were affiliated with the Land Use Section of the then Northern Prairie Wildlife Research Center (NPWRC). Besides evaluating old and developing new techniques, all members of the Section were involved in inventory studies to determine what species of upland nesting birds were using the different habitat types available in the Northern Great Plains Region (1, 7, 8, 9, 10, 11).

THE HABITAT MANIPULATION YEARS

We recognize 1969-1985 as the period of research to evaluate waterfowl production in relation to land use manipulations and established fields of dense nesting cover. One of the earliest studies by Leo Kirsch compared duck nesting success between native mixed grass pastures that were grazed season-long and recently idled native mixed grass fields (7). He found duck production was better on idled than on grazed native pastures. However, after a few years, duck production on idled native prairie generally declined, after which researchers began new studies evaluating duck nesting in grasslands treated periodically with fire (2, 12) and haying (8, 13), or those developed specifically for wildlife such as grasslands, commonly called "seeded" or "dense" nesting cover (2).

In addition to the studies emphasizing upland habitat manipulations to enhance production and survival of prairie ducks, several supplemental studies were conducted involving other management techniques or species. Included among these studies were those of shorebirds (4, 13, 14, 15, 16); nesting structures (17); island nesting (18, 19, 20); non-game birds (21, 22, 23, 24); and terrestrial passerine birds that will be reported on by Johnson (25) and upland vegetation that will be reported on by Meyer (26).

THE RECENT YEARS

We recognize the recent years of 1986-1995 as the post waterfowl research years even though some duck studies, duck and brood counts, and grassland burns continued through 1995 (M. Callow, pers. comm., N.H. Euliss, Jr., pers. comm.). In September 1989, however, much of the former waterfowl research ceased on the WSA. When the major thrust of the former waterfowl research studies at the WSA was terminated in 1988, it marked the end of the only long-term ecological research effort of waterfowl in the glaciated prairie pothole region of the United States. The data sets from the WSA studies are now archived at the NPSC. Many of the data sets are still being used by other researchers (e.g., Reynolds and Johnson in this symposium) to augment their research or to facilitate development of waterfowl population models. They likewise remain available for comparison should waterfowl studies begin anew.

In 1992, Higgins and others (2:pages 63 and 64) proposed the following for the future of the WSA:

"We recommend that long-term waterfowl studies be continued at the Woodworth Study Area (WSA) and additional locations within broad ecological habitat associations in the glaciated prairie pothole region. Most waterfowl ecology field studies have been relatively short-term because of graduate school tenure, funding allocations, and employee transfer. Even when graduate studies are sequential (e.g., three consecutive 2-year master's programs), their total is still relatively short-term."

"If future long-term studies are to be conducted on the WSA or some similar large tract of land, we would also recommend using aerial photography and remote-sensed data to evaluate land use changes, vegetation changes, and wet-dry conditions of wetlands. Use of these procedures would greatly enhance data accuracy and would provide better permanent records of the overall terrestrial aspects for any future study."

"Upland-nesting waterfowl were emphasized during this study; in future studies we would recommend more emphasis on over-water nesting waterfowl and shorebirds. We would also recommend a more integrated study approach with special emphasis on predator effects and behavior and on buffer-prey species abundance, particularly of small mammals, passerines, amphibians, and insects."

"Our native prairie habitat research was limited to season-long grazing and to mostly spring burning management. We support expanding of the research to include additional types of specialized grazing systems and to fall burning efforts, both of which show initial promise for increasing waterfowl production for private as well as public lands, and in wetlands as well as uplands."

Unfortunately for waterfowl and other wetlands biota and for the resource managers responsible for stewardship of lands dedicated to wildlife production and welfare, we conclude that the intensive waterfowl research at WSA was terminated prematurely in 1988. Why do we conclude that it was premature? First, a tremendous set of baseline data was available on which to initiate future research. Research plans proposed for post-1985 included land treatments combining grazing systems and prescription fires for both uplands and wetlands. Research also was planned to assess game and non-game bird use of wetlands subjected to various habitat treatments.

Second, 1987 was the beginning of a very extreme series of drought years (1988-1992) followed by a series of extremely wet years (1993-1995). One of the early charges of the WSA staff was to monitor and evaluate the effects of fluctuating climate on wildlife populations and their habitats. In retrospect, one of the greatest opportunities in the past 30 years was missed. In addition to the waterfowl studies, a similar opportunity was missed with the long-term monitoring of permanently marked vegetation transects. From the time burning was first initiated on the WSA (circa 1966), we were never able to measure the vegetation response in a series of extreme drought or wet years as were experienced during 1988-1995.

Third, future plans had already been drafted to use the on-going research and the WSA lands and wetlands as a demonstration and education center to better acquaint scientists, resource managers, farmers, ranchers, and other interested citizens with land use and other practices such as nesting structures and islands that would enhance benefits and reduce risks to the production of ducks and other prairie and wetland wildlife commonly found in the northern Great Plains Region of the U.S. and southern Canada.

Fourth and last, computer technological advances plus new statistical analytical procedures were finally available post-1985 that would better enable analysis of large, multiple data sets such as occurred for the WSA studies.

In the words of Harvey K. Nelson from the Foreword of Higgins et al. (2), "As with any research program, increasing demands for new investigations were not always matched by additional funds and personnel." Likewise, administrative research prioritization were not always matched with the everyday needs of resource managers and the resource -- the termination of the long-term monitoring and land use research relative to waterfowl and other prairie wildlife at the WSA emphasizes the overall effects of such actions. This observation provides particular insight when one considers that the WSA was one of, if not the, largest grassland tracts in North America where all treatments were totally controlled for research purposes. An obvious conclusion is that such sites should remain high on the list of priority study areas for any new waterfowl research in the Northern Great Plains.

1. Miller, H. W. (1971) Relation of duck nesting success to land use in North and South Dakota. Intern. Congress Game Biol. 10,133-139.

2. Higgins, K. F., Kirsch, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl production on the Woodworth Station in south-central North Dakota, 1965-1981. U.S. Fish Wildl. Serv. Resour. Publ. 180.

3. Klett, A. T. and Kirsch, L. M. (1976) Diurnal use of small wetlands by ducks. J. Wildl. Manage. 40,351-353.

4. Higgins, K. F., Kirsch, L. M. and Ball, I. J., Jr. (1969) A cable-chain device for locating duck nests. J. Wildl. Manage. 33,1009-1011.

5. Higgins, K. F., Kirsch, L. M., Duebbert, H. F., Klett, A. T. Lokemoen, J. T. Miller, H. W. and Kruse, A.D. (1971) Construction and operation of a cable-chain drag for nest searches. U.S. Fish Wildl. Serv. Wildl. Leaflet 512.

6. Klett, A. T., Duebbert, H. F., Faanes, C. A. and Higgins, K. F. (1986) Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. U.S. Fish Wildl. Serv. Resour. Pub. 158.

7. Kirsch, L. M. (1969) Waterfowl production in relation to grazing. J. Wildl. Manage. 33,821-828.

8. Oetting, R. B. and Cassel, J. F. (1971) Waterfowl nesting on interstate highway right-of-way in North Dakota. J. Wildl. Manage. 35,774-781.

9. Duebbert, H. F. and Kantrud, H. A. (1974) Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38,257-265.

10. Nelson, H. K. and Duebbert, H. F. (1974) New concepts regarding the production of waterfowl and other game birds in areas of diversified agriculture. Internat. Intern. Congress Game Biol. 11,385-394.

11. Higgins, K. F. (1977) Duck nesting in intensively farmed areas of North Dakota. J. Wildl. Manage. 41,232-242.

12. Kirsch, L. M. and Kruse, A. D. (1973) Prairie fires and wildlife. Proc. 1972 Annu. Tall Timbers Fire Ecol. Conf. 12,289-303.

13. Kirsch, L. M. and Higgins, K. F. (1976) Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4,16-20.

14. Higgins, K. F. and Kirsch, L. M. (1975) Some aspects of the breeding biology of the upland sandpiper in North Dakota. Wilson Bull. 87,96-102.

15. Higgins, K. F. (1974) Shorebird and game bird nests in North Dakota croplands. Wildl. Soc. Bull. 3,176-179.

16. Higgins, K. F., Kirsch, L. M., Ryan, M. R. and Renken, R. B. (1979) Some ecological aspects of marbled godwits and willets in North Dakota. Prairie Nat. 11,115-118.

17. Higgins, K. F., Miller, H. W. and Kirsch, L. M. (1986) Waterfowl nesting on an earth-filled cement culvert. Prairie Nat. 18,115-116.

18. Johnson, R. F., Jr., Woodward, R. O. and Kirsch, L. M. (1978) Waterfowl nesting on small man-made islands in prairie wetlands. Wildl. Soc. Bull. 6,240-243.

19. Higgins, K. F. (1986) Further evaluation of duck nesting on small man-made islands in North Dakota. Wildl. Soc. Bull. 14,155-157.

20. Aufforth, A. D., Goetz, H. and Higgins, K. F. (1990) Duck nesting on islands at J. Clark Salyer Refuge in North Dakota, 1983-1984. Prairie Nat. 22,1-12.

21. Higgins, K. F., Kirsch, L. M. and Callow, J. M. (1980) Spring arrival of birds at Woodworth, North Dakota. Prairie Nat. 12,89-91.

22. Higgins, K. F., Arnold, T. W. and Barta, R. M. (1984) Breeding bird community colonization of sown stands of native grasses in North Dakota. Prairie Nat. 16,177-182.

23. Arnold, T. W. and Higgins, K. F. (1986) Effects of shrub coverages on birds of North Dakota mixed-grass prairies. Can. Field-Nat. 100,10-14.

24. Kantrud, H. A. and Higgins, K. F. (1992) Nest and nest site characteristics of some ground-nesting, non-passerine birds of northern grasslands. Prairie Nat. 24,67-84.

25. Johnson, D. H. (1996) Terrestrial bird communities on the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

26. Meyer, M. I. (1996) Upland vegetation at the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

WOODWORTH DATA AND PLANNING FOR THE PRAIRIE POTHOLE JOINT VENTURE

Ronald E. Reynolds[1]* and Michael A. Johnson[2]

[1]U.S. Fish and Wildlife Service, Habitat and Population Evaluation Team, 1500 East Capitol Avenue, Bismarck, ND 58501 and [2]North Dakota Game and Fish Department, 100 North Bismarck Expressway, Bismarck, ND 58501

The North American Waterfowl Management Plan (1, NAWMP) was created in 1986 in response, primarily, to declining duck populations in North America. Under the NAWMP, focus areas, called Joint Ventures, were identified where management actions were considered critical to the long term welfare of waterfowl resources. The Prairie Pothole Joint Venture (PPJV), which includes the prairie pothole area of North Dakota, South Dakota, Montana, Minnesota, and Iowa, is considered a high priority joint venture of the NAWMP.

Between 1991 and 1994, a planning process was conducted in the PPJV area of North Dakota, South Dakota, and northeastern Montana to determine the type and amount of management treatment that would be necessary to meet the population objectives established for the Joint Venture (2). This planning process, called Multi-Agency Approach to Planning and Evaluation (MAAPE), involved participants from numerous government and non-government conservation organizations. The strategy was to bring appropriate information to bear on the fundamental components of the planning exercise. A major part of the exercise focused on biological information necessary to identify factors responsible for declining duck numbers and management treatments needed to reverse the decline.

From 1963 to present, the Woodworth Study Area (WSA) and surrounding area in southcentral North Dakota was a major focus area for waterfowl research and management trials conducted by the U.S. Fish and Wildlife Service (and recently the National Biological Service). Much of the information generated from these studies was used in the MAAPE process to answer questions and solve problems.

During the period 1966-81, over 3,300 duck nest records were accumulated at the WSA (3). These records and others gathered at WSA through 1984 were an important part of the nest records used by researchers to conclude that nest success in most of the U.S. Prairie Pothole Region was inadequate to maintain populations of upland nesting ducks and that predation was the most important cause of nest failure (4). This understanding was crucial to developing strategies that focused on treatments which reduced nest losses to predators.

Many of the treatments considered in the MAAPE process were designed to manipulate upland habitats in such a way that the cover was attractive to nesting hens and provided relative security from nest predators. A study conducted during 1974-76 at WSA defined a positive relationship between the height-density of grass cover and its attractiveness to nesting female ducks and their success (5). Numerous other subsequent studies have solidified these earlier findings and have led to treatments such as managed grazing, conversion of cropland to planted cover, and programs that idle perennial grass cover to increase the height-density of vegetative cover.

Increasing duck production in some landscapes requires intensive treatments. Studies at WSA have improved management's understanding of treatments such as nesting structures and small created islands (6, 7), which have become an integral part of the PPJV plan. In addition to influencing nest hatch rates of ducks, predators also prey on nesting hens. Understanding the magnitude of various mortality factors is imperative to developing proper management strategies for any wildlife population. Studies conducted, in part, in the WSA have demonstrated that predators such as red fox take a large number of nesting hens (8, 9), which accounts for a substantial portion of annual hen mortality. This information supports management initiatives that increase nest success because reduction in hen mortality can also be expected.

In summary, WSA has played a key role in advancing the understanding of waterfowl biology in the northern plains. It is beyond the scope of this paper to summarize all of the contributions of the station to waterfowl management. WSA has served as a laboratory for wetland and waterbird ecology and a headquarters for similar research in the surrounding land area. Numerous ideas about "how ducks operate" were conceived and tested at the station. Recently developed tools such as the Mallard Model (10) have synthesized data from duck studies at WSA and elsewhere in the Prairie Pothole Region so that managers can simulate the production potential of landscapes with various habitat configurations and make decisions about treatments. Such population models and advances in landscape assessment technology have resulted in a level of planning that far exceeds that available only a few years ago. The future value of this planning exercise will depend on efforts to continue collecting data to update and strengthen model weaknesses as landscape and wildlife components change.

---

1. U.S. Fish and Wildlife Service and Canadian Wildlife Service. (1986) North American Waterfowl Management Plan.

2. U.S. Prairie Pothole Joint Venture. (1995) Implementation Plan Update.

3. Higgins, K. F., Kirsch, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl production on the Woodworth Station in southcentral North Dakota, 1965-1981. U.S. Fish Wildl. Serv. Resour. Publ. 180.

4. Klett, A. T., Shaffer, T. L. and Johnson, D. H. (1988) Duck nest sucess in the Prairie Pothole Region. J. Wildl. Manage. 52,431-440.

5. Kirsch, L. M., Duebbert, H. F. and Kruse, A. D. (1978) Grazing and haying effects on habitats of upland nesting birds. Trans. N. Am. Wildl. Nat. Resour. Conf. 43,486-497.

6. Higgins, K. F. (1986) Further evaluation of duck nesting on small man-made islands in North Dakota. Wildl. Soc. Bull. 14,155-157.

7. Higgins, K. F. (1986) A comparison of burn season effects on nesting birds in North Dakota mixed-grass prairie. Prairie Nat. 18,115-116.

8. Johnson, D. H. and Sargeant, A. B. (1977) Impact of red fox predation on the sex ratio of prairie Mallards. U.S. Fish Wildl. Serv. Wildl. Res. Rept. 6.

9. Sargeant, A. B., Allen, S. H. and Eberhardt, R. T. (1984) Red-fox predation on breeding ducks in midcontinent North America. Wildl. Monogr. No. 89.

10. Cowardin, L. M., D. H. Johnson, T. L. Shaffer and D. W. Sparling. (1988) Applications of a simulation model to decisions in mallard management. U.S. Fish Wildl. Serv., Fish Wildl. Tech. Rept. 17.

EFFECTS OF FIRE RETARDANT CHEMICALS AND FIRE SUPPRESSANT FOAM ON NORTH DAKOTA PRAIRIE VEGETATION

Diane L. Larson* and Wesley E. Newton
National Biological Service
Northern Prairie Science Center
8711 37th Street Southeast
Jamestown, ND 58401

INTRODUCTION

Fire suppressant foams and fire retardant chemicals are used in wildland fire control and in prescribed burns for habitat management. In 1988 alone, more than 5 million gallons of retardant chemicals were dropped from aircraft on wildland fires in the western United States (1). Class A foams, the type typically used in wildland fire suppression, also receive widespread use in constructing fire lines for prescribed burns. Some 210,000 gallons of concentrate -- enough to make 42 million gallons of foam -- were sold in 1992 (C. Johnson, pers. comm.). Despite their relatively widespread use, little is known about their potential effects on terrestrial and aquatic ecosystems. A literature search at the beginning of this study revealed only two published scientific articles on ecological effects of fire retardant chemicals used for wildfire suppression: one on aquatic toxicity (2) and one on annual grassland response (3). No studies have been published on ecological effects of Class A foams.

Because these chemicals most often are used in natural areas and areas set aside for wildlife, the fire suppression community has identified a need to determine their potential effects on ecosystems. In response to this need, three National Biological Service Science Centers have undertaken research to determine ways in which fire retardants and foams affect both terrestrial and aquatic ecosystems. Patuxent Environmental Science Center took the lead on terrestrial bird, small mammal, and invertebrate responses; Midwest Science Center has evaluated effects on aquatic organisms; and Northern Prairie Science Center has examined responses in terrestrial plant communities. Taken together, these studies provide land managers and fire control professionals with a starting point in establishing guidelines for safe use of fire retardant chemicals and fire suppressant foams.

The purpose of this portion of the study was to examine experimentally the effect of retardant and foam application on vegetation. We studied the effects alone and in combination with fire. In addition, we examined the effects of the chemicals and fire on insect herbivory, which provides a link to higher levels in the food chain. The first year's work was conducted in the structurally simple mixed-grass prairie, so that general patterns could be identified. Subsequent studies are being done in more complex habitat.

Our objectives were to estimate effects of fire suppressant foam and fire retardant chemical application on growth and species diversity of burned and unburned prairie vegetation, and to assess the response of herbivorous insects, in terms of number of insects and their effects on plants, to burning and application of foam and retardant to their host plants.

DESCRIPTION OF STUDY SITE

The study was conducted at the Woodworth Study Area, a research site of the Northern Prairie Science Center, Jamestown, N.D. The 65-ha field containing the study site has never been plowed. Biologists burned the field in 1969, 1970, 1971, 1972, 1976, 1979, 1981, and 1990; it has not been grazed since 1974. Currently, vegetation in the study area is dominated by *Poa pratensis*, an exotic cool-season grass. Other grass species found during previous studies on the site include *Stipa viridula*, *S. comata*, *Agropyron repens*, *Muhlenbergia cuspidata*, and *Bromus inermis*. *Rosa arkansana*, *Elaeagnus commutata*, and *Symphoricarpos occidentalis* are common woody plants.

DESCRIPTION OF CHEMICALS

We used one Class A foam -- Silv-Ex -- and one fire retardant -- Phos-Chek G75-F -- in our field tests. Silv-Ex concentrate is a proprietary mixture of sodium and ammonium salts of fatty alcohol ether sulfates, higher alcohols, and water, as well as butyl carbitol and ethyl alcohol (4). It functions as a surfactant, allowing water to penetrate and expand over the surface of fuels so that they retain moisture longer. Silv-Ex, like other Class A foams, is applied operationally either from ground tankers or helicopters.

Phos-Chek G75-F is a formulation composed of monoammonium phosphate and ammonium sulfate, fugitive coloring agent, and small amounts of gum-thickener, bactericide and corrosion inhibitor (5). It is typically applied from helicopter bucket or ground tanker in advance of a fire; other retardants with higher viscosity are applied from fixed-wing aircraft. The ammonium salts retard fire by chemically combining with cellulose as fuels are heated, as well as through evaporative cooling of the fuels (6).

METHODS

We delineated a grid of 30 0.4-ha blocks in the study field (Figure 1). Each block was separated from adjacent blocks by a mowed, 5-m-wide fire break. Four treatments for the foam study [burning (B), foam application (F), burning and foam application (BF), and no manipulation (C)] were each assigned at random to six blocks. We established a 10 m x 10 m plot in the center of each of these 24 blocks for vegetation sampling (Figure 1). For the retardant study, we established five 10 m x 10 m vegetation plots in each of the remaining six 0.4 ha blocks. Four treatments [burning (B), retardant application (R), retardant application plus burning (RB), and no manipulation (C)] were assigned at random to one of the five plots within 0.4 ha blocks; each 0.4 ha block had each of the four treatments. Vegetation plots for which the treatment included burning were surrounded by mowed 1.5 m wide fire breaks.

Inside each 10 m x 10 m vegetation plot we randomly selected five 1-m^2 permanent vegetation subplots and four 0.25-m^2 biomass subplots (Figure 1). Prior to treatment, we counted stems of *S. occidentalis* and *R. arkansana*, counted the total number of plant species, and measured litter depth in each permanent vegetation subplot. We made all pretreatment measurements during 17 - 28 May 1993.

Retardant application and burning of retardant plots was accomplished on May 26. Representatives of Monsanto applied Phos-Chek G75-F at the rate of 1 gallon per 100 ft^2, resulting in approximately 12 pounds of retardant per plot, to the R and RB plots within each 0.4 ha block. This is the application rate recommended for grassland vegetation. The retardant was applied by hand using a hose from a slip-on pumping unit. We burned the RB plots after retardant had been applied and allowed to dry for 0.5 - 1 hour. B plots were also burned at this time.

On 1 June the 0.4 ha B and BF blocks were burned. All fires were allowed to burn to completion; vegetation was reduced to ash. On 10 June we applied Silv-Ex in 0.5%-solution maintained by a proportioner to F and BF blocks. The rate of application was approximately 189 liters per 10 m x 10 m plot, resulting in approximately 1 liter of Silv-Ex concentrate on each 10 m x 10 m vegetation plot. Only the vegetation plots were treated on BF blocks. The foam was applied from a 3.66-m boom mounted on bicycle tires and pushed by two people. Nozzles mounted on the boom every 30 cm each produced approximately a 1:10 expansion.

We measured the length of two fully expanded leaves on each species except *P. pratensis*. We measured the total length and counted the number of galls, leaf miners, aphids, chewed leaves, and flowers on each of the five shoots. Galls, leaf miners, aphids, and chewed leaves were recorded on a per-leaf basis. In each permanent subplot, we counted the total number of plant species and measured litter depth at four locations. Total stems of *S. occidentalis*, *R. arkansana*, and *S. rigida* were also recorded in each plot at each sample period.

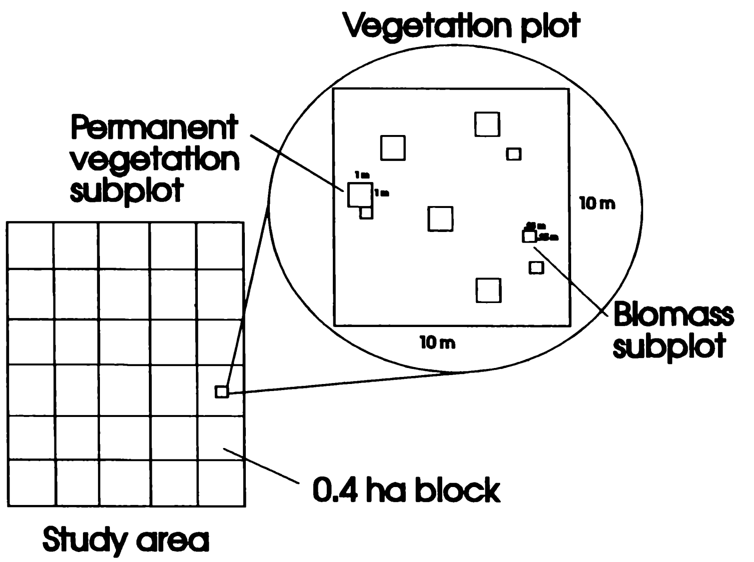


Figure 1. Study area, showing 0.4-ha blocks, 10 m x 10 m vegetation plots, and randomly located 1-m^2 permanent vegetation subplots and 0.25 m x 0.25 m biomass plots.

We conducted post-treatment vegetation sampling at 2-week intervals, beginning June 16 and ending August 27. We concentrated on four species: *P. pratensis*, *S. occidentalis*, *R. arkansana*, and *Solidago rigida*. Height of *P. pratensis* was measured at four locations on each subplot at each sampling period. For the other three species, we marked individual plants in each permanent vegetation subplot as follows: two *S. occidentalis*, two *R. arkansana*, and ten *S. rigida*. If fewer individuals were found in a subplot, we marked all found individuals. Plants were marked near the base with either blue or red flagging (*R. arkansana* and *S. occidentalis*), or numbered metal tags (*S. rigida*). Current year's growth was followed on five shoots through the three sampling periods on each *S. occidentalis* and *R. arkansana* plant.

Two of the 0.25 m x 0.25 m biomass subplots were clipped to ground level on 23-29 June and 7-8 September, 1993 and 14-15 July, 1994 (retardant); and 7-8 July and 9-10 September, 1993 and 11-12 July, 1994 (foam). Dead and woody vegetation was removed and discarded. Live non-woody vegetation was oven dried to constant weight and weighed.

STATISTICAL METHODS

We used analysis of variance (ANOVA) techniques in a repeated-measures type design with subsampling to assess the effects of the burn-foam treatments, time since treatment, and their interaction on all measured variables. Mean separations of significant effects in the ANOVAs were done with Fisher's protected least significant difference value (7). Analyses were made in the original scale of measurement and with a $\log(y+1)$ transformation (8), but only results in the original scale of measurements are reported because only slight differences were observed in ANOVA results. ANOVAs were done using the General Linear Models procedure of SAS (9). Significance was set at the 0.05 level.

Because vegetation plots differed significantly in number of plant species at pre-treatment in the foam study, this difference was taken into account in subsequent analysis by using the change in number of species between pre- and post-treatment as the response variable. Plots were similar in all other pre-treatment measurements for both the retardant and foam studies.

RESULTS, DISCUSSION, AND MANAGEMENT IMPLICATIONS

Fire Suppressant Foam

Overall, Silv-Ex application had little affect on the vegetation characteristics we measured. Effects we detected were subtle. Of the 24 response variables, only five showed significant ($P < 0.05$) effects of Silv-Ex application (Table 1). Change in number of species, ratio of chewed to total leaves per shoot in *S. occidentalis* and *R. arkansana*, and mean shoot length and leaf length in *S. occidentalis* were affected by treatment.

The number of plant species increased between pre- and post- treatment in all plots, but the increase was smaller in plots treated with Silv-Ex ($\bar{x} = 1.53 \pm 0.26$) than in untreated plots ($\bar{x} = 2.34 \pm 0.26$). Burning did not influence this difference.

Because the summer of 1993 was exceptionally cool and wet, insect abundances were low at our study site (D. Larson, personal observation). However, Silv-Ex application influenced herbivory, as evidenced by the proportion of chewed leaves on *S. occidentalis* and *R. arkansana* (Figure 2). Silv-Ex treated plants of both species experienced greater herbivory late in the season; more untreated *R. arkansana* leaves were chewed early in the season. Herbivory on burned *Rosa* was not affected by Silv-Ex.

Silv-Ex application had little affect on herbaceous plant growth, as evidenced by the lack of difference in herbaceous biomass accumulation between treated and untreated plots, irrespective of burning (Figure 3). Growth characteristics of *S. occidentalis* were affected, however. Leaf length increased more rapidly on plants treated with Silv-Ex than on untreated plants (Figure 4). Burning significantly enhanced the rate of shoot growth compared with other treatments; Silv-Ex tended to depress shoot growth. The decline in shoot length between June and July for Silv-Ex treated plants suggests senescence, shoot damage and subsequent breakage, or vertebrate herbivory.

Fire Retardant Chemical

Of the 24 response variables, five showed a significant effect involving Phos-Chek treatment (Table 1). Phos-Chek G75-F application resulted in increased biomass, whether or not the plots were burned (two-way nested ANOVA; $F = 18.61$; df = 1, 15; $P = 0.0006$). No interaction between retardant and burning was evident ($F = 0.84$; df = 1, 15; $P = 0.3726$). The effect was transitory, however; biomass did not differ among treatments the following year (Figure 3).

Larson and Duncan (10) documented similar changes in herbaceous biomass in a California oak-savanna rangeland after a diammonium phosphate (DAP) retardant was applied to extinguish an October fire. Herbage yield the season after application was significantly higher on plots to which DAP had been applied, whether burned or unburned. By the second season, DAP plots were statistically indistinguishable from burned, untreated plots.

The fertilization effect in our study seemed to be concentrated in *P. pratensis*. Grass not only was longer on plots treated with retardant, but the effect was enhanced over the course of the growing season (Figure 5). Measures of shoots and leaves on woody species, and of stem length on *Solidago*, did not indicate any affect on growth of these species.

Phos-Chek influenced the number of leaves per shoot in *S. occidentalis* (Figure 6). Early in the season, retardant produced similar changes in leaf production on burned and unburned plants. However, between July and August the relationship changed: only burned, untreated plants were still producing leaves.

Of concern to land managers is the potential depression in species richness associated with both Silv-Ex (Table 1) and Phos-Chek (Figure 7) application. The change in number of species per plot was significantly lower after Silv-Ex application, regardless of whether or not the plot was burned. The change in number of species per plot was depressed, especially between July and August, on Phos-Chek plots.

Table 1. Summary of vegetation characteristics measured and significant effects of Silv-Ex and Phos-Chek application. Significant effects may include interactions with sampling month or burning (see results).

Variable		Foam effect[1]	Retardant effect[1]
Change in number of species		*	*
Shoot growth,			
	S. occidentalis	**	
	R. arkansana		
Total growth,			
	S. rigida		
	P. pratensis		***
Number of stems,			
	S. occidentalis		
	R. arkansana		
	S. rigida		
Leaves/shoot,			
	S. occidentalis		*
	R. arkansana		
Leaf length,			
	S. occidentalis	*	
	R. arkansana		
	S. rigida		
Number of sprouts,			
	S. occidentalis		
	R. arkansana		
Number of galls/leaf,			
	S. occidentalis		
	R. arkansana		
	S. rigida		
% chewed leaves,			
	S. occidentalis	*	
	R. arkansana	(*)	
	S. rigida		
Herbaceous biomass,			
	June/July 1993		***
	September 1993		***
	July 1994		

[1](*) = P=0.06; * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

All plots were dominated by *P. pratensis*, which clearly benefitted from retardant fertilization, and also may have increased in response to the general disturbance, crowding out other species. Greater than average precipitation during the first growing season after treatment also may have influenced *P. pratensis* growth. Work in Wisconsin has suggested a larger positive response in *P. pratensis* to burning in mesic compared with xeric sites (10). Further work in areas not dominated by *P. pratensis* will help define this relation.

Implications of this research depend on the objectives of the land manager. If the objective is to halt an uncontrolled fire, subtle changes caused by Silv-Ex and Phos-Chek may be of little importance. On the other hand, if the objective is to aid in the control of prescribed burns, the potential effect on species richness should be considered. In particular, if the control of exotic, robust grasses such as *P. pratensis* is important, these results suggest that use of these chemicals should be avoided.

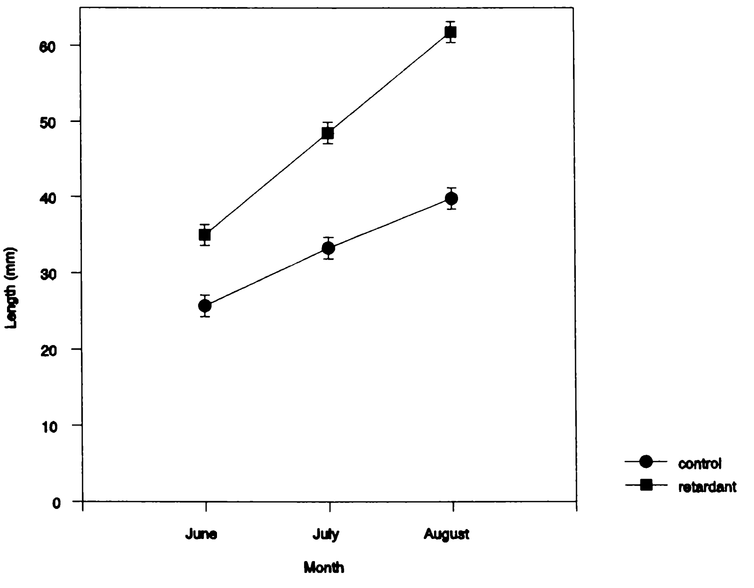


Figure 2. Mean (± one SE of the mean for the retardant x month interaction) length of *P. pratensis* for plots treated or not treated with Phos-Chek, regardless of burn treatment.

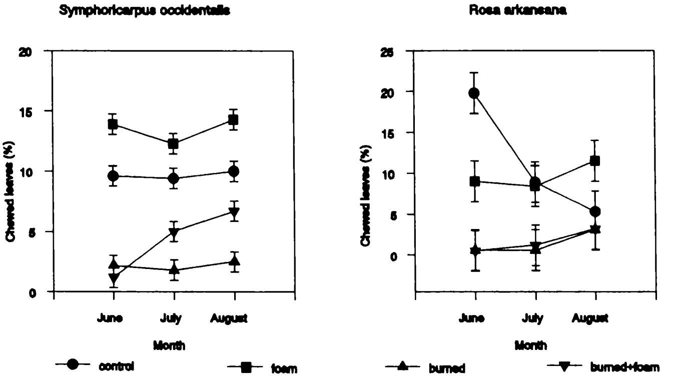


Figure 3. Ratio of chewed to unchewed leaves on *S. occidentalis* and *R. arkansana*. Shown is the mean ± one SE of the mean for the 3-way interaction foam x fire x month.

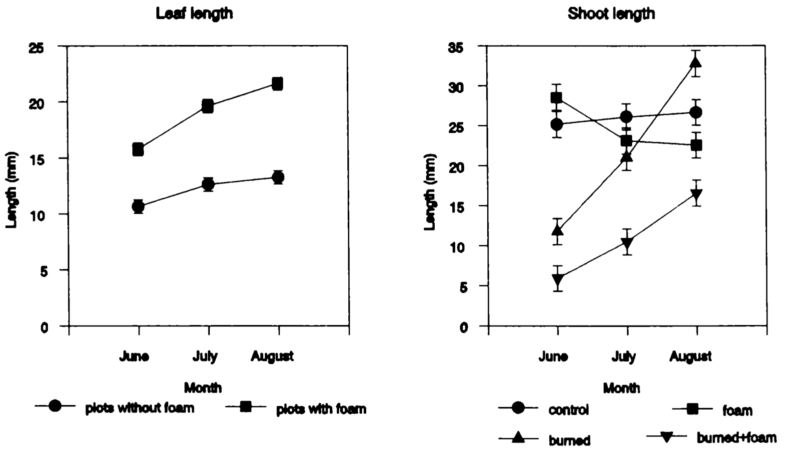


Figure 4. Plants treated or not treated with Silv-Ex (a) Mean (± SE) leaf length on *S. occidentalis* and (b) mean (± SE) shoot length on *S. occidentalis*.

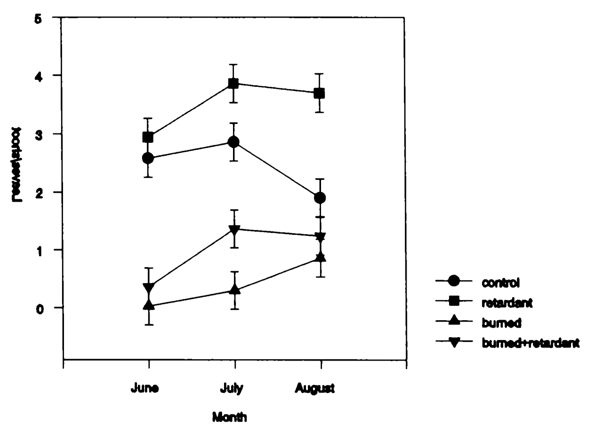


Figure 5. Mean (± one SE of the mean for the retardant x fire x month interaction) number of leaves per shoot on *S. occidentalis*, Phos-Chek experiment.

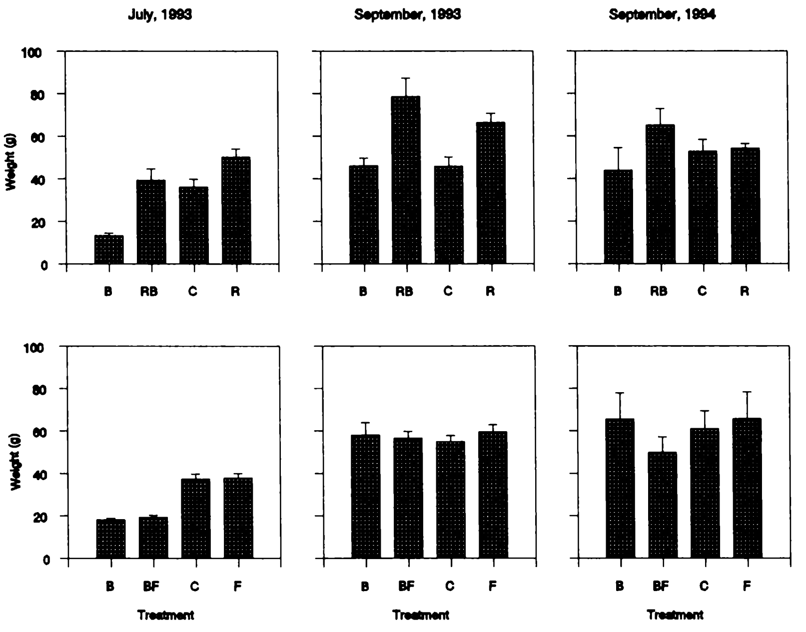


Figure 6. Mean (± one SE of the mean) herbaceous biomass accumulation, 4, 12, and 56 weeks post-treatment with (a) Phos-Chek and (b) Silv-Ex.

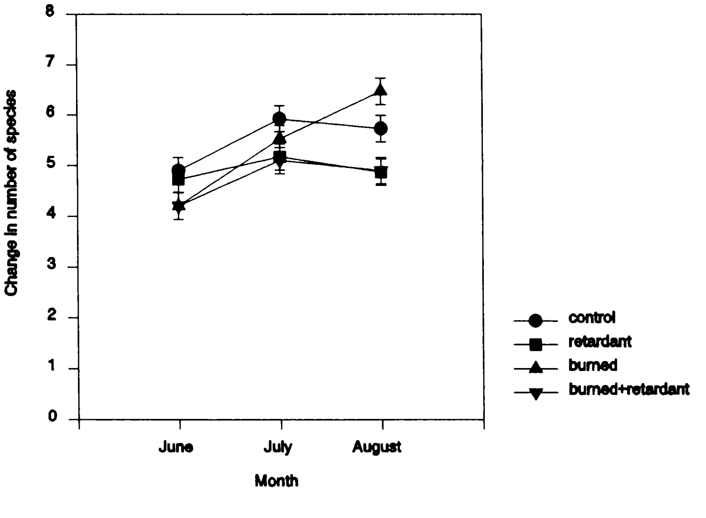


Figure 7. Change in mean number of species per plot between pre- and post-treatment, with and without Phos-Chek application and burning. Error bar indicates one SE of the mean.

1. Guth, A. R. and Cohen, S. B. (1989) Red skies of '88: the 1988 forest fire season in the northern Rockies, the northern Great Plains and the Greater Yellowstone Area. Pictorial Histories Publ. Co., Missoula, MT.

2. Johnson, W. W. and Saunders, H. O. (1977) Chemical forest fire retardants: acute toxicity to five freshwater fishes and a scud. Tech. Paper #91, U.S. Forest Service.

3. Larson, J. R. and Duncan, D. A. (1982) Annual grassland response to fire retardant and wildfire. J. Range Manage. 35,700-703.

4. Ansul Fire Protection. (1994) Material safety data sheet: Silv-Ex. Ansul Fire Protection, One Stanton St., Marinette, WI.

5. NWCG Fire Equipment Working Team. (1991) Field quality control of fire retardant chemicals. Boise Interagency Fire Center, Publ. NFES 1245.

6. Lyons, J. W. (1970) The chemistry and uses of fire retardants. Wiley-Interscience, New York.

7. Milliken, G. A. and Johnson, D. E. (1984) Analysis of messy data, volume I: designed experiments. New York, NY: Van Nostrand Reinhold Co.

8. Steel, R. G. D. and Torrie, J. H. (1980) Principles and procedures of statistics. A biometrical approach, 2nd edition. New York, NY., McGraw-Hill, Inc.

9. SAS Institute Inc. (1989) SAS/STAT user's guide. Version 6, fourth edition, volume 2. Cary, NC: SAS Institute Inc.

10. Zedler, J. and Loucks, O. L. (1969) Differential burning response of *Poa pratensis* fields and *Andropogon scoparius* prairies in central Wisconsin. Am. Midl. Nat. 81,341-352.

EFFECTS OF TWO FIRE SUPPRESSANT FOAMS ON BENTHIC INVERTEBRATES COLONIZING ARTIFICIAL SUBSTRATES IN PORTABLE LIMNOCORRALS

Barry C. Poulton*
National Biological Service
4200 New Haven Road
Midwest Science Center
Columbia, MO 65201

Fire retardant chemicals are used extensively in the United States for suppression and control of range and forest fires. Each year, fire control agencies utilize millions of gallons of fire retardants on a wide array of ecosystems, including environmentally sensitive areas which may contain endangered, threatened, or economically significant plant and animal species. Although some laboratory information is available concerning the toxicity of fire chemicals (1, 2,), relatively little information is available concerning their impacts on aquatic fauna.

In June 1993, we conducted field studies to evaluate *in-situ* effects on aquatic invertebrates in a prairie ecosystem in central North Dakota. Based on preliminary laboratory tests (2), the suppressant foams Ansul Silv-Ex and Phoschek WD881 are known to be more toxic to aquatic organisms than liquid retardants. Laboratory-determined effective concentrations of two commonly used foams were tested in order to fulfill the following objectives: 1) to determine *in-situ* effects on aquatic macroinvertebrate communities, and 2) to determine the toxicity of these chemicals to a selected indigenous invertebrate found in the aquatic system.

DESCRIPTION OF STUDY AREA

Field studies were conducted at the Woodworth Study Area (WSA), a Field Station of the Northern Prairie Science Center, located in the Missouri Coteau physiographic region of central North Dakota (Stutsman County, Township 142N, Range 68W, Section 11). Fish Lake, a 30-acre permanent wetland basin, was used for the test. In the recorded history of WSA, including the drought of the 1930's, Fish Lake has never dried completely.

METHODS

One 96 hr *in-situ* field exposure was performed on June 5-9, 1993. Portable, octagonal limnocorrals were used to enclose approximately 2500 L of lake water. The 2.5 m wide x 1 m high enclosures were constructed from 1.5" diameter PVC pipe and fittings with a bottom edging of 1/4" polyethylene to create a seal during placement into soft sediments. Limnocorrals were encircled with 10-mil polyethylene and built with a 4-way PVC center cross to strengthen the frame and divide the limnocorral into 4 quadrants. At depths ranging from 55-60 cm, 1" galvanized conduit pipe was placed at each of 24 consecutively numbered locations along a single transect in Fish Lake. This pipe was used for anchoring and positioning the enclosures and for attachment of artificial invertebrate substrates. A 5-cm hole was drilled in the center of each limnocorral to aid in positioning the enclosure onto the conduit pipe.

To provide a relatively uniform community of aquatic invertebrates for the exposure, artificial substrate trays constructed of 1/2" mesh aquaculture netting and a base of 1/8" polyethylene and 3/4" PVC pipe were deployed on May 10, 1993 for a colonization period of 4 weeks. The trays contained 5 g of pre-weighed, air-dried Cottonwood (*Populus deltoides*) leaves. A total of 120 substrate trays were deployed with a nylon pull cord attached to the conduit pipe at each of the 24 limnocorral locations, 4 to be enclosed in each limnocorral (1 in each quadrant) and one reference tray outside each limnocorral. Substrates were sampled by pulling the nylon cord vertically and placing the trays in zip-lock bags with 90% ethanol preservative. On June 4, the 24 trays outside the limnocorrals were sampled before limnocorral placement to provide a reference for determination of community similarity and allow detection of disturbance effects associated with limnocorral placement. At 24 hours before the exposure, limnocorrals (8 Silv-Ex, 8 Phos-Chek WD-881, 8 control) were placed in Fish Lake to enclose the remaining 96 colonized artificial substrates, which were sampled after the 96 hr. exposure.

To determine the toxicity of these chemicals to an indigenous invertebrate, the water boatman *Cenocorixa* sp. (Hemiptera: Corixidae) was collected from Fish Lake on June 5 prior to chemical addition. Ten *Cenocorixa* sp. were placed in 15 L polyethylene chambers fitted with 1 mm mesh netting, and suspended from the frame in each limnocorral 1 hr after chemical addition. Number of organisms remaining alive was recorded daily throughout the test.

Chemical concentrations representing the lowest observable effect level (LOEL) based on laboratory test data for *Daphnia magna* (3) were used for the Fish Lake exposure (Silv-Ex = 6 mg/L, Phoschek WD881 = 4.7 mg/L). Chemicals were pre-weighed in the laboratory and added as a liquid to numbered limnocorrals in a randomized fashion.

Self-contained dataloggers (DataSonde II™ units, Hydrolab Inc., Austin, Texas; use of brandnames does not constitute endorsement by the U.S. Government) were used to measure pH, dissolved oxygen, conductivity, and water temperature at hourly intervals throughout the exposure. Units were suspended at mid-depth in Fish Lake and within randomly selected limnocorrals (2 Silv-Ex, 2

Phos-Chek WD881, 2 control). One liter water samples were also collected from each limnocorral and the open water areas between 0700-0900 h for determination of dissolved oxygen, Ammonia, orthophosphorus (EPA method 365.1, Colorimatic Automated Ascorbic Acid Method), and pH daily throughout the test period. Nitrate, nitrite, chlorides, sulfates, alkalinity, and hardness were measured once before and once after the 96 hr exposure (4).

RESULTS

Fish Lake is an alkaline, well-buffered aquatic ecosystem. The pH ranged from 8.3 to 8.7 with mean hardness and alkalinity of 1345 and 766 mg/L as $CaC0_3$, respectively. Daily patterns in temperature, pH, dissolved oxygen, and conductivity did not differ among or between limnocorrals and the open water of Fish Lake, and no dose-related fluctuations in phosphates, sulfates, chlorides, chlorophyll *a*, conductivity, or pH occurred during the exposure.

Aquatic macroinvertebrate taxa richness in Fish Lake was extremely low; only 18 taxa were collected in the artificial substrate trays, and the 5 most dominant taxa were chironomids (Table 1). Seven reference trays and those in 5 of the limnocorrals (3, 21-24) were covered with sediment and could not be used for analysis. Taxa richness, relative abundance, and mean number of organisms did not differ among treatments (Figures 1, 2). Mean number of organisms in reference trays was lower as compared to trays inside the enclosures, however disturbance effects due to placement of the limnocorrals were not detected. The Pinkham and Pearson Similarity Index indicated that for both total number of organisms and relative abundance, treatments did not differ from controls (Figure 3).

After 24 hr, exposure to 6 mg/L Silv-Ex resulted in significantly higher mortality of water boatmen (*Cenocorixa* sp.) than in controls (P = 0.003, Figure 4). The most dramatic decrease in survival (69%) occurred during the first 24 hr, but survival continued to decrease throughout the 96-h Silv-Ex exposure until only 11% of the organisms remained. Contrastingly, the 4.7 mg/L Phoschek WD881 treatment did not cause mortality significantly different from that of controls (Figure 4). However, organisms showed impaired movement that suggested a sublethal response related to chemical exposure.

DISCUSSION

Under field conditions, the dose-response of *Cenocorixa* exposed to 6 mg/L Silv-Ex was similar to that observed in laboratory exposures with other aquatic organisms (3). In both instances, the highest mortality occurred during the first 24 hours (Figure 4). In the event of an actual spill or accidental overspray, chemical concentration would be highest during the first 24 hours because degradation begins immediately; under laboratory conditions, Silv-Ex degrades by 42% in about 20 days (5). However, under natural conditions, that degradation may be accelerated. Based on toxicity of suppressant foams to fish (6), it is likely that the mortality observed in our study was related to the surfactants and their effect on reduction of surface tension, which probably caused impairment in mobility and respiration of the water boatmen.

Chemical concentrations used in this study were not high enough to cause reductions in invertebrate species abundance or taxa richness. It is unlikely that our inability to detect subtle community changes was due to the sampling technique used; artificial substrates often provide samples with low variability (7), as was the case in this study. With the exception of limnocorrals 2 and 13, taxa richness and numbers of organisms in most samples taken during this study were within a relatively small range (Figures 1, 2), and no effects due to chemical exposure were detected. The community which colonized the leaf substrates may not have included species that were sensitive to reductions in surface tension. Future determinations of community effects should include exposure to higher chemical concentrations.

Using a field application example, where chemical spillage or overspray might occur, the concentration of 6 mg/L Silv-Ex used in our study is equivalent to a spill of 1.5 L of a 1% Silv-Ex mixture directly into one 2500 L limnocorral, or a spray coverage rate of 0.75 gal/100 ft^2. Assuming even coverage, if a 1% Silv-Ex mixture was applied at the recommended application rate for grassland prairie ecosystems (5 gal/100 ft^2), the resulting concentration in one limnocorral would be 40 mg/L. This concentration is 167% higher than that producing significant mortality of larval fathead minnows (*Pimephales promelas*) in both field and laboratory exposures (8). Since dilution of an affected area would be rapid, it is unlikely that a concentration this high would actually occur. Nonetheless, water boatmen and other invertebrates that utilize the water surface could suffer adverse effects from direct chemical exposure. Even though these organisms and other invertebrates such as daphnids and amphipods are neither economically or recreationally important aquatic resources, they are an integral part of the food chain essential to the support of higher trophic levels such as fish and birds.

Acknowledgment--This project was supported by the Interagency Fire Coordination Committee.

Table 1. Benthic invertebrate taxa collected by artificial substrates in Fish Lake, Stutsman County, North Dakota on June 4-9, 1993 during an evaluation of the effects of 2 fire suppressant foams on aquatic organisms.

ACARINA
TRICHOPTERA
- Family Leptoceridae
  - *Mystacides* sp.
  - *Oecetis* sp.
  - *Triaenoides* sp.

COLEOPTERA
- Family Dytiscidae
  - Hydroporini larvae

DIPTERA
- Family Ceratopogonidae
  - *Bezzia* sp.
- Family Chironomidae
  - *Ablabesmyia* sp.
  - **Chironomus* sp.
  - **Dicrotendipes* sp.
  - *Eukiefferiella* sp.
  - **Hydrobaenus* sp.
  - *Lenziella* sp.
  - **Parachironomus* sp.
  - **Paracricotopus* sp.
  - *Procladius* sp.
  - *Tanypus* sp.
  - *Tanytarsus* sp.
- Family Ephydridae

*Indicates the 5 most dominant taxa

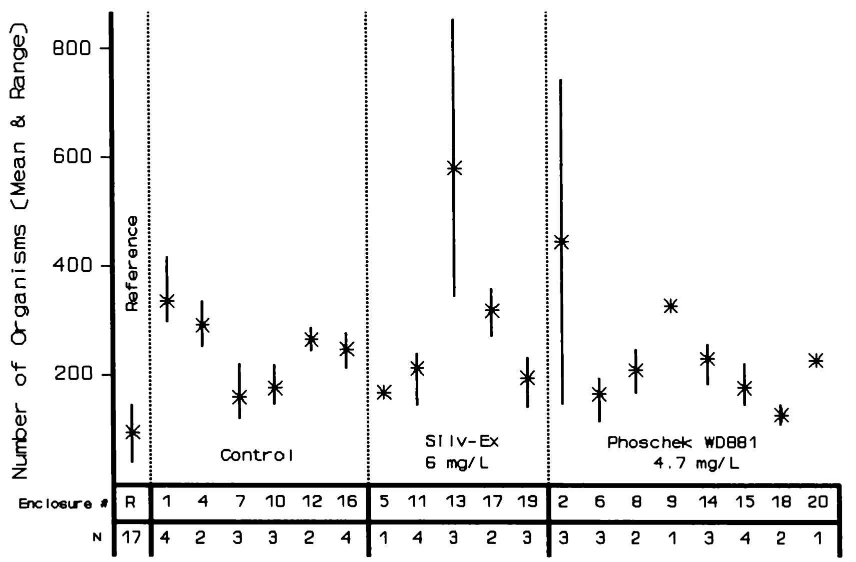


Figure 1. Mean number of invertebrates collected by artificial substrate trays as part of the evaluation of effects of 2 fire suppressant foams on aquatic organisms in Fish Lake, North Dakota.

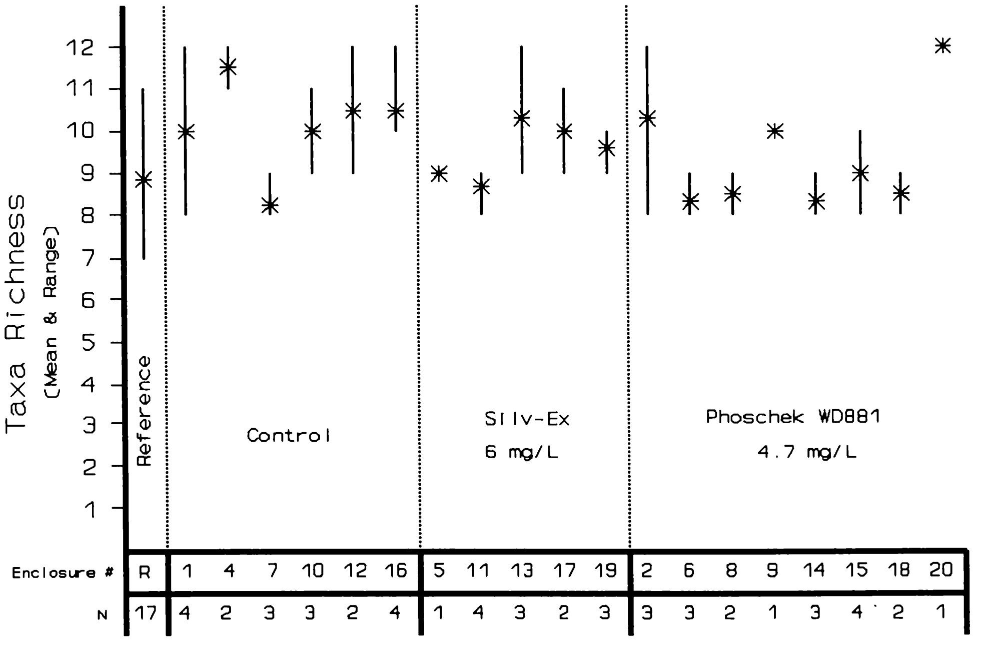


Figure 2. Mean taxa richness of invertebrates collected by artificial substrates as part of the evaluation effects of 2 fire suppressant foams on aquatic organisms in Fish Lake, North Dakota.

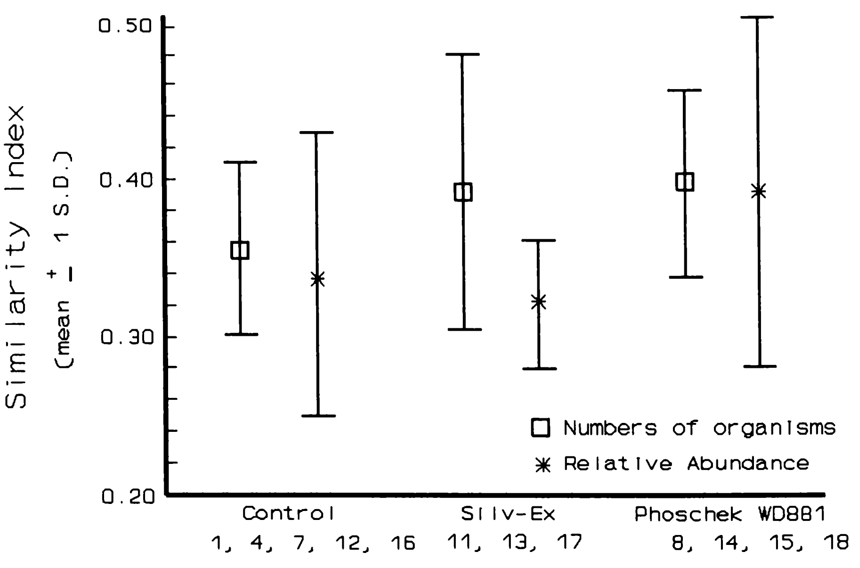


Figure 3. Pinkham and Pearson's Similarity Index for abundance and total numbers of macroinvertebrates exposed to fire suppressant foams during the limnocorral study in Fish Lake, North Dakota.

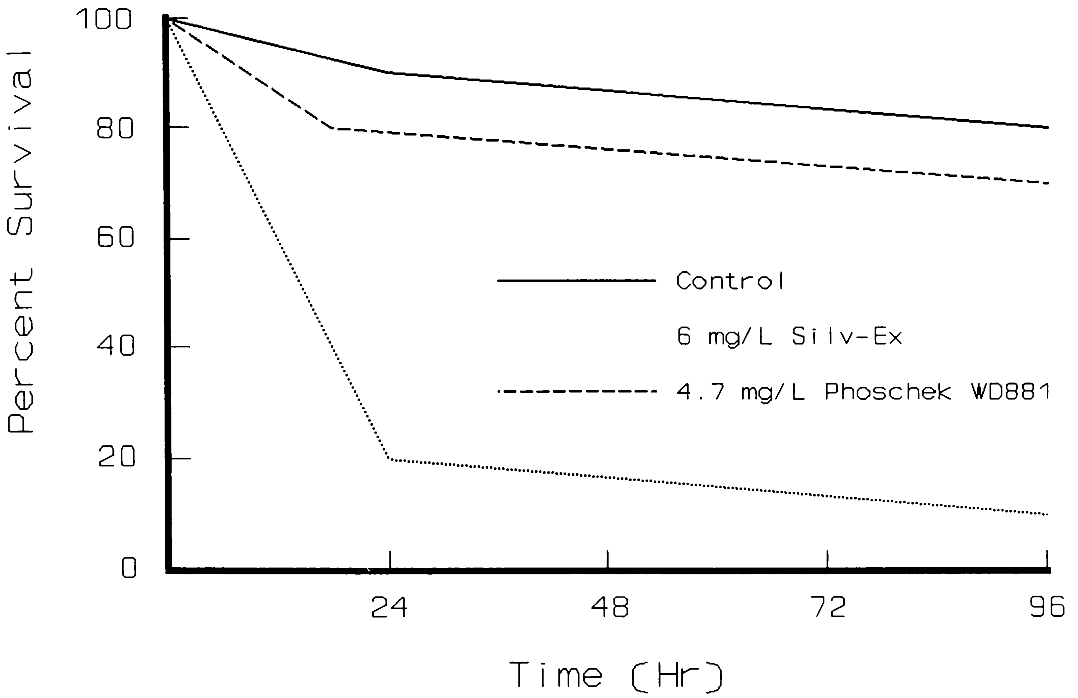


Figure 4. Survival of Cenocorixa sp. (water boatman) after the 96 hour limnocorral exposure to Silv-Ex and Phoschek WD881 in Fish Lake, North Dakota.

---

1. Johnson, W. W. and Sanders, H. O. (1977) Chemical forest fire retardants: acute toxicity to five freshwater fishes and a scud. Tech. Paper #91, U.S. Forest Service.

2. Gaikowski, M. P., Hamilton, S. J., Buhl, K. J., McDonald, S. F. and Summers, C. H. Environ. Toxicol. and Chem., in review.

3. Hamilton, S. J. (1993) Toxicity of fire retardant and foam suppressant chemicals to plant and animal communities. S. E. Finger, *ed.*, Progress Report #1, prepared for Interagency Fire Coordination Committee, Boise, ID.

4. American Public Health Association. (1985) Standard methods for the examination of water and wastewater. 16th edition, Washington, D.C.

5. Norecol Environmental Consultants, LTD. (1989) Toxicological review of fire fighting foams. Report prepared for Manager, Fire Management, Forest Canada.

6. Muller, R. (1980) Investigations of antifoam agents. J. Fish. Biol. 16,585-589.

7. Rosenberg, D. M. and Resh, V. H. (1982) The Use of artificial substrates in the study of freshwater benthic macroinvertebrates. pp. 175-236, *in* Cairns, J., Jr., *ed.* Artificial Substrates. Ann Arbor Science Publishers, Ann Arbor, MI.

8. Poulton, B. C. (1994) Toxicity of fire retardant and foam suppressant chemicals to plant and animal communities. S. E. Finger, *ed.*, Progress Report 2, Interagency Fire Coordination Committee, Boise, ID.

EFFECTS OF SILV-EX® ON TERRESTRIAL WILDLIFE

Nimish B. Vyas*, James W. Spann, and Elwood F. Hill
National Biological Service
Patuxent Environmental Science Center
11510 American Holly Drive
Laurel, Maryland 20708

INTRODUCTION

The U.S. Bureau of Land Management (BLM) and the U.S. Forest Service are the primary agencies responsible for the control of wildfires on public lands in the United States. These fires may be anthropogenic or of natural origin and may strike forests, rangelands or grasslands. Wildfires may occur in habitats that support endangered species. Resource agencies must decide whether fires should be allowed to burn and potentially destroy the habitat or whether they should be controlled using chemicals that may possibly be toxic to endangered species or impact critical habitats. Three National Biological Service Science Centers are collaborating to develop environmentally sound wildfire management strategies with regards to the use of chemicals. The Patuxent Environmental Science Center is studying the impacts of the wildfire control chemicals on terrestrial vertebrates and invertebrates. The Northern Prairie Science Center and the Midwest Science Center are responsible for determining the impacts of the chemicals on terrestrial vegetation and aquatic species, respectively.

Foams are one class of wildfire control chemicals. Foams exclude oxygen from burning fuels and allow for a slower release and a more efficient use of water (1). Silv-Ex® (Ansul Corporation; use of brandnames does not constitute endorsement by the U.S Government) is a commonly used wildfire control foam and was therefore recommended for laboratory and field testing by the BLM and the National Interagency Fire Center, Boise, Idaho. Acute and subacute toxicity of Silv-Ex® is reported to be low for white-footed mice (*Peromyscus leucopus*), Northern bobwhites (*Colinus virginianus*), American kestrels (*Falco sparverius*), and red-winged blackbirds (*Agelaius phoeniceus*). Acute oral limit tests for single-dose 24-h median lethal dosages (LD50) were greater than 2,000 mg Silv-Ex®/kg body weight. Subacute dietary limit tests demonstrated that five-day median lethal concentrations (LC50) were greater than 5,000 mg Silv-Ex®/kg body weight. Silv-Ex® was selected for field testing based on the results of the laboratory aquatic toxicity tests (2) and the paucity of information on its impact on mammals and birds. This work was funded by the National Interagency Fire Center, Boise, Idaho.

The objectives of our study were to, 1) determine the population-level effects of Silv-Ex® on small mammals, 2) determine the reproductive success of birds exposed to Silv-Ex®, 3) determine the effects of Silv-Ex® on the abundance and diversity of insects, and 4) determine residue levels of Silv-Ex® on vegetation.

Small mammals were selected for primary focus in our study since they are not highly mobile and were expected to be exposed to the chemical within the treated area. Birds, however, likely foraged outside the study site. Further, the density of small mammals was expected to be greater within the study area than birds. Eggs and nestlings of birds nesting in the study sites were to be monitored because they may be exposed to the chemical via direct contact or ingestion.

METHODS

Our study was conducted at the Woodworth Study Area (WSA), North Dakota. Two treatments were selected, control and 0.3% Silv-Ex®. The 0.3% Silv-Ex treatment is the most common Silv-Ex® concentration used for the control of grassland fires (Wiesse, pers. comm.).

To assess the response of small mammal and insect populations, 12 1-acre (0.4 ha) plots (6 controls and 6 treatments of 0.3% Silv-Ex®) were sampled pre- and post-application for approximately 3 months (May - August, 1993). Estimates of small mammal abundance and survival were conducted using live mark-recapture methodology. Experimental design followed the combined closed and open population models (3). One hundred Sherman live traps were arranged in a 10 X 10 matrix on the control and Silv-Ex® plots. Small mammals were individually marked with Monel metal fingerling tags or Avid pits and immediately released at the capture site. Data on body weight and reproductive condition were recorded at the initial capture and at all subsequent recaptures. Each plot was sampled immediately prior to treatment (pre-treatment sampling) to determine species diversity and abundance. Plots were sampled three times following treatment (post-treatment sampling). A total of 1,200 small mammal live traps (100 traps per plot) were checked every day for 5 consecutive days at 2 week intervals. Estimates of survival rate and population size were determined and the treatment effect was evaluated with a t-test.

The reproductive success of birds nesting in and around the study site was to be monitored for hatching success and nestling survival. However, due to inclement weather, the initiation of breeding by birds was delayed until well after chemical application. Therefore, no data were collected on the impact of Silv-Ex® on avian reproduction.

The effects of Silv-Ex® on insect abundance and diversity was to be measured using standard sweep nets. Methods involved sweeping the nets along ten transects across each plot. Because of excessive rain and cool temperatures, sweep netting in plots resulted in collection of only a few individuals. Therefore, we sampled ants from mounds located in the study plots. Two mounds (one on a control plot and one on a treated plot) were sampled once pre-treatment, and twice post-treatment. The two mounds were similar in that they measured approximately 40 cm high and their flat tops were 20 cm in diameter. Adhesive packaging tape (2.54 cm width) the length of the diameter of the mound was place across the flat top of the mound (adhesive side down). The tape and ants were quickly placed in a zip-lock bag and refrigerated prior to counting. Sampling per mound was conducted in triplicates. Treatment effect was assessed with a t-test.

Vegetation samples were collected for analysis of residue levels of Silv-Ex®. Forty grams per sample were collected from three randomly selected locations in each plot. Samples were frozen and shipped to Patuxent for analysis.

RESULTS AND CONCLUSIONS

Small mammal trapping data indicated the meadow vole, *Microtus pennsylvanicus* was the most common mammal species. Other species trapped included the thirteen-lined ground squirrel (*Citellus tridecemlineatus*) and *Peromyscus* spp. Only the meadow vole was abundant enough for statistical analysis. No treatment effect was found on the survival rate ($P=0.3490$) and the population size ($P=0.9938$) for the meadow vole. We also were unable to identify a treatment effect on ants ($P>0.05$).

The WSA was subject to extremely high amounts of precipitation during summer 1993. The area also experienced cooler temperatures than average. We believe this weather was responsible for our small sample size of mammals and insects. Only about 30% of the traps were successful during each trapping period. This was considerably lower than the trapping success (70-80%) we obtained in a similar experiment in Nevada. The small sample size may have masked the treatment effect. Further, we believe that excessive rain events may have diluted the level of Silv-Ex® in our treatment plots and transported it away from the treatment area.

---

1. Schlobohm, P. and Rochna R. (1988) An evaluation of foam as a fire suppressant is available. National Wildlife Coordination Group. Foam Applications Wildlife and Urban Fire Management 1,6-7.

2. Poulton, B. C. (1996) Effects of two fire suppressant foams on benthic invertebrates colonizing artificial substrates in portable limnocorrals. Proc. N.D. Acad. Sci. 50.

3. Pollock, K. H., Nichols, J. D., Brownie, C. and Hines, J. E. (1990) Statistical inference for capture-recapture experiments. Wildl. Monog. 107.

LINKING RESEARCH WITH MANAGEMENT: A HISTORICAL PERSPECTIVE

Harvey K. Nelson
First Director, Northern Prairie Wildlife Research Center
U.S. Fish and Wildlife Service - Retired
10515 Kell Ave., South
Bloomington, MN 55437

INTRODUCTION

The maintenance of healthy wetland and upland environments for desired populations of waterfowl and other migratory birds depends on increasing sophisticated management programs for public and private lands. Knowledgeable professionals must learn to work together to make such programs successful. New management techniques, properly researched and tested, need to be made available to managers and incorporated into broader programs as quickly as possible. These were some of the basic principles incorporated into the initial program of the Northern Prairie Wildlife Research Center (NPWRC) when established in 1963. My good fortune was to have been involved in the early planning and direction of that program, including the establishment of the Woodworth Field Station (1).

I want to take this opportunity to pay tribute to the early team of researchers and managers that guided the planning and development of the research and monitoring programs conducted there. They were Leo Kirsch (Deceased), Harvey Miller (Retired), Thomas Klett (Retired), Harold Duebbert (Retired), Paul Springer (Retired), Kenneth Higgins, David Trauger, Robert Oetting (Deceased); and during the later years Reid Goforth, Douglas Johnson, and Michael Callow.

BACKGROUND

During the formative years of the NPWRC program (1963-1966), special emphasis was given to determining the status of ongoing, related research being planned or conducted by other federal, state and provincial agencies, universities and private conservation organizations in the United States and Canada. The objective was to identify priority research needs, where such might best be conducted, and to avoid duplication of effort. These coordination efforts also focused on interdisciplinary cooperation and the need for other scientific support to supplement NPWRC capabilities at that time. Some examples were the use of burning in grassland management, water quality investigations, and the seasonal hydrology of small wetlands.

Other principles of the NPWRC program were to: 1) Plan and conduct a balanced short-term and long-term research program that would address priority issues confronting the management of migratory birds and their habitats in North America. Primary emphasis was on wetland and grassland ecology, waterfowl breeding ecology, and the impacts of agricultural land use practices on waterfowl production in the Prairie Pothole Region (PPR). This was an early approach to ecosystem research and management. 2) Provide timely information to wildlife managers and administrators, other private land managers, farmers and ranchers on best management practices that would maximize benefits to wildlife. 3) Coordinate research efforts with agricultural agencies to identify program activities that offer potential for application of research results to habitat conservation practices. 4) Publish research results and recommendations promptly in peer-reviewed journals and agency report series. At the same time, make periodic progress reports and significant new information available to managers through technical assistance procedures. 5) Whenever possible, encourage the incorporation of improved land and water management practices that would enhance wildlife values in the program criteria for farm programs administered by state departments of agriculture and the U.S. Department of Agriculture (USDA). 6) Give priority to research for current management needs of the U.S. Fish and Wildlife Service (USFWS) and the international migratory bird management program (2, 3, 4).

The Woodworth Study Area (WSA), as referred to in this symposium, was officially designated in 1963 as the Woodworth Field Station (WFS) of the NPWRC then being established at Jamestown, ND. The WSA is a large block of continuous habitat containing about 1070 ha. It was originally purchased as a waterfowl production area (WPA) and expanded to meet research requirements as the NPWRC program evolved. Other WPAs in the immediate area were also made available for special studies under management agreements with regional wetland management officials (5).

The WFS met the program criteria for providing a sizable tract of land in the Missouri Coteau, within 80 km of the Center for conducting long-term research on habitat changes and response by prairie waterfowl. The unit was to be representative of the PPR, in an area of mixed grassland and agriculture, and with a high density of wetlands. The intent was to establish and maintain a long-term study area, where baseline data would serve present and future studies. The primary mission of the WFS was to test specific hypotheses and conduct research concerning the best land and water management practices that would also maximize benefits to wildlife. The primary emphasis was on migratory birds, especially waterfowl production, in keeping with the mission of NPWRC. The impact of land management practices on resident species (sharp-tailed grouse, ring-necked pheasant, white-tailed deer and small mammals) was included in the long-term monitoring program.

It was recognized that a large percentage of wildlife species in the PPR are produced and raised on private land. Thus, it would be essential to analyze land and water management practices that might be modified to increase wildlife benefits, yet be economically feasible and acceptable to land owners. Improved management practices applicable to public land were also included in the early stages of the research and field testing program. The initial studies focused on the response of wildlife to applied treatments of grazing, burning, idling of grassland and crop land, and annual cropping with rotation. Later studies included the development of better monitoring and evaluation techniques, and specialized equipment to facilitate individual research projects. Special studies of critical species were conducted when applicable and compatible with other NPWRC research priorities. Many studies were conducted as graduate student projects.

When one reflects on the research conducted by the Center and the WFS during the past 33 years, it is clear that there have been many changes in emphasis, management philosophies, priorities and scientific capabilities. During recent years, reduced budgets and staff have restricted the scope of the research. In 1994, the NPWRC was transferred from the USFWS to the newly established National Biological Service (NBS) and renamed the Northern Prairie Science Center (NPSC). Long-term monitoring of habitat conditions and waterfowl production was terminated in 1988, but cooperative research efforts with more broadly ecological focus with less emphasis upon waterfowl were continued through 1995.

OVERVIEW OF ACCOMPLISHMENTS

During the past 30 years, the NPWRC (now NPSC) has provided a wealth of published information on prairie wetland and grassland ecosystems, the breeding ecology of waterfowl and other migratory birds, the impact of predation on waterfowl and other ground nesting birds, and the effects of various land use practices on wildlife on public and private lands. The papers in this symposium by Johnson et al. (6) and Johnson (7) contain a partial list of publications emanating from studies conducted by NPWRC scientists and others that involved the WSA. The paper by Higgins and Woodward (8), summarized much of the work conducted there. That paper has an extensive listing of references resulting from research and applied management studies conducted during the 30 year period. Many cooperators were involved over the years. A specific example from the earlier years was the prairie pothole hydrology study conducted in cooperation with the U.S. Geological Survey (USGS) that yielded significant new information on the relationship of surface runoff and groundwater recharge to the annual hydrologic cycle of small wetlands (9).

As noted by other presenters at this symposium, the scientists and managers involved were eminently successful in achieving the research and management objectives assigned. The WFS, hereafter referred to as WSA, developed an international reputation for its work in developing the dense nesting cover concept, maintaining desired native grassland succession through prescribed burning, determining optimum frequency for habitat manipulation, identifying the effects of mammalian predation on nesting ducks and other birds, and for providing a better understanding of the effects of wet and dry cycles on waterfowl production.

Another measure of accomplishment is the application of research results to local, regional, and international problems and programs. The following examples illustrate how the combined efforts of the NPWRC and the WSA have been used in that context.

- Provided new information for wetland hydrology concepts and programs of the USFWS, USGS, Natural Resources Conservation Service (NRCS), and the U.S. Army Corps of Engineers (COE).
- Reinforced knowledge of the values of seasonal wetlands to waterfowl production.
- Identified the true impact of mammalian predation on production by waterfowl and other ground nesting birds, and the role of dense cover in reducing such impacts.
- Developed the dense nesting cover concept that is being applied internationally in wildlife management and land retirement programs.
- Provided new information on the use of prescribed burning to maintain optimum grassland conditions for nesting waterfowl, other migratory species, and resident species.
- Reinforced values of land retirement programs of the U.S. Department of Agriculture (Soil Bank, Water Bank, set aside acres) to wildlife.
- Provided strong scientific and socio-economic support for the 1980 and 1985 Farm Bills with data resulting from studies at WSA and the Mid-Continent Waterfowl Project at Fergus Falls, MN that led to the current Conservation Reserve Program (CRP). Similar information was used in developing programs for wetland restoration on private lands, and the Wetland Reserve Program (WRP).
- Applied pertinent habitat management techniques to Canadian programs through close coordination and interchange of current information with federal and provincial agencies and private natural resource organizations in Canada.

- Provided data bases from 1984-1986 to prepare the North American Waterfowl Management Plan and the 1994 update. This information was also used extensively in the establishment of the Joint Ventures under the plan and development of 15 Joint Venture Management Plans (10, 11, 12).

- Focused new emphasis on the seasonal food requirements of prairie waterfowl and the importance of invertebrates in diets of adults and ducklings through limnological studies.

- Shed new light on the species composition and growth forms of plants preferred by waterfowl and other migratory birds through grassland studies.

RECENT ACCOMPLISHMENTS THROUGH INTERDISCIPLINARY RESEARCH

A number of the papers presented in this symposium reflect the value of having a long-term study area available to conduct research and the value of extending the scope of work by involving other interested agencies and disciplines. After reviewing the papers in this category, I selected four examples to emphasize the value of interdisciplinary research and the linkage to management.

1. "Impact of agricultural land-use on prairie wetland ecosystems: experimental design and overview" by R.A. Gleason and N.H. Euliss, Jr., NBS.

   This was a cooperative venture between NBS, the U.S. Environmental Protection Agency (EPA), COE, National Research Council (NRC), University of Minnesota and Humboldt State University.

   The objective was to determine the effect of sedimentation on water quality, vegetative growth, invertebrates, agricultural chemical content, and waterfowl use. Definitive information on these inter-relationships was not previously available for this area.

   The results indicated that soil loss was greatest on land in summer fallow, followed by bufferstrips, CRP and native prairie. No difference in waterfowl use was detected but the new information is important to land managers because it documents accelerated sedimentation that leads to eventual loss of wetland habitat.

2. "Effects of water level changes on prairie pothole vegetation structure and diversity in the Woodworth Study Area" by D.L. Taylor and N.E. Detenbeck, EPA.

   Vegetative diversity and community structure were monitored for two years on seasonal wetlands. Observations were made on surrounding land use (tilled, bufferstrips, CRP and native prairie). Changes in vegetative diversity and height, and changes in succession were recorded as water levels increased due to heavy rains.

   Changes were measurable and quantified, and tended to support general knowledge of vegetative response to rising water levels. Grasses decreased in abundance and were replaced by sedges. The wet meadow zones supported aquatic species as the vegetative zones changed with rising water levels. Incorporation of expertise in botany and hydrology provided measurable results that were important to wetland managers.

   Other papers by Vieux et al. (13;COE), Detenbeck et al. (14;EPA), and Wrubleski (15;NRC) provided additional new information on sedimentation modeling, water quality, and invertebrate production potential of prairie potholes.

3. "Effects of fire retardant chemicals and fire suppressant foam on North Dakota prairie vegetation" by D.L. Larson and W.E. Newton, NBS.

   Although fire retardant chemicals and fire suppressant foams are used extensively in wildland fire control and prescribed habitat burns, little is known about the potential effects on terrestrial and aquatic ecosystems. The objective was to examine experimentally the effect of retardant and foam application on vegetation and associated insect populations, alone and in combination with fire.

   Although results may be somewhat indefinite because of the wet field seasons during the two-year study, they provided new information to managers. A simple interpretation is that foam (Silv-Ex) had little effect on plant growth, but tended to depress shoot growth. The retardant used (Phos-Chek G75-F) produced a pronounced fertilization effect and an increase in plant growth, but a depression in species richness. From the viewpoint of managers, if the objective is to halt uncontrolled fires, subtle changes caused by either retardant may be of little importance. When used in prescribed burns, however, the potential effect on species richness should be considered by the applicator.

   Other papers presented on the effects of fire retardant chemicals on vegetative structure, diversity, invertebrate populations, and small mammals by Poulton (16; NBS) and Vyas et al. (17; NBS) provide additional examples to aid applicators.

4. "Woodworth Data in Planning for the Prairie Pothole Joint Venture." by R.E. Reynolds and M.A. Johnson.

Data from the WSA provided baseline information for developing the Mallard Model and the Multi-Agency Approach to Planning and Evaluation (MAAPE). Both models enable managers to simulate the waterfowl population and production potential of landscapes with various configurations, and to make decisions about the most appropriate treatments. These new tools have been recognized as significant contributions to permit more effective implementation of the North American Waterfowl Management Plan.

THE BENEFITS OF INTERAGENCY AND INTERDISCIPLINARY RESEARCH AND DEVELOPMENT

This symposium session has helped focus attention on the many benefits that can be derived from interagency and interdisciplinary cooperation. Although these concepts were incorporated in the early research programs of the NPWRC and the WSA under the USFWS, they offer further opportunities during this new era of ecosystem management, investigation of biological diversity, and partnership arrangements now being promoted to enhance natural resource research and management. These concepts also are in conformance with the guiding principles for the NBS. It is important, however, that such efforts continue to be focused on priority resource management issues. Some of the major benefits are:

* Permits the pooling of knowledge and resources, and broadens the base of interest and support.

* Helps focus attention on priority issues.

* Provides an effective mechanism for delivery of short-term and long-term research guidance for specific management needs.

* Improves cost effectiveness of research effort and translation to management application in a timely manner.

* Helps build credibility within the scientific community.

* Enhances research image at administrative and political levels.

FUTURE CONSIDERATIONS

Joint ventures, partnerships, and other cooperative arrangements will usually stimulate better systematic planning and more rapid agreement on priorities for important natural resource issues. This, in turn, will permit more effective use of available research funds. When researchers seek the assistance of other disciplines as needed, they enhance their overall scientific capability and should be able to deliver a better product. This may prove to be a vital factor for maintaining a high visibility role for research in the years ahead. This becomes especially significant under restricted agency and university budgets, and attempts to de-emphasize environmental studies.

The delivery of timely information that addresses priority management issues and public concerns is an important tool for increasing public understanding of ecological relationships involved in proper management of the Nation's natural resources.

The importance of long-term studies and designated areas on which to conduct research is well recognized by the scientific community. Unfortunately, this concept appears to be losing support under most of the present political and administrative entities responsible for administering natural resource and environmental programs. It also is unfortunate that during times of restricted budgets for federal and state agencies, research is usually the first function to be reduced or eliminated. Looking specifically at the WSA, such actions began in 1988, although research still has priority access to the land under an agreement with USFWS and management of the site still emphasizes research priorities. I believe there is a need to maintain the WSA concept here in the Midwest as it applies to the Prairie Pothole Region. I am pleased to learn that negotiations between NPSC and USFWS to continue research activities there have been successful. The new arrangement does not jeopardize the USFWS's needs for its Chase Lake Prairie Project and maintains the integrity of NPSC's research facilities. The agreement between USFWS and NPSC indeed is a model for others to emulate. I also believe that other physiographic regions could be served in a similar manner where there is an established need. The real problem is development of a support base that will provide adequate funding to carry out such interagency and interdisciplinary research and monitoring programs. This may be difficult to achieve under present budget restrictions and changing philosophies. Nevertheless, successful experiences from the past should help guide the future. Again, the WSA is a model worth applying elsewhere.

---

1. Nelson, H. K. (1992) in (5), piii.

2. Nelson, H. K. (1966) Progress in development of a new wildlife research center. N.D. Outdoors. 28,12-16.

3. Nelson, H. K. and Lee, F. B. (1966) A new center for waterfowl research. Naturalist. 17,29-32.

4. Nelson, H. K. and Duebbert, H. F. (1974) New concepts regarding the production of waterfowl and other gamebirds in areas of diversified agriculture. 11th International Congress of Game Biologists. Debrecen, Hungary.

5. Higgins, K. F., Kirsh, L. M., Klett, A. T. and Miller, H. W. (1992) Waterfowl production on the Woodworth Study Area in South-Central North Dakota. U.S. Fish Wildl. Serv. Resour. Publ. 180.

6. Johnson, D. H., Higgins, K. F. and Woodward, R. O. (1996) An introduction to the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

7. Johnson, D. H. (1996) Terrestrial bird communities on the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

8. Higgins, K. F. and Woodward, R. O. (1996) Waterfowl studies at the Woodworth Study Area, Stutsman County, North Dakota: 1965-1995. Proc. N.D. Acad. Sci. 50.

9. Eisenlohr, W. S. Jr., et al. (1972) Hydrologic investigations of prairie potholes in North Dakota. U.S. Geol. Surv. Prof. Paper 585-A.

10. U.S. Department of the Interior and Environment Canada (1986) North American Waterfowl Management Plan. U.S. Fish Wildl. Serv., Washington, D.C. (Updated 1994).

11. Patterson, J. H. and Nelson, H. K. (1988) Progress in implementation of the North American Waterfowl Management Plan. Trans. N. Am. Wildl. Nat. Res. Conf. 53,24-28.

12. Nelson, H. K., Streeter, R. G. and McCuaig, J. D. (1991) Accomplishments of the North American Waterfowl Management Plan. Trans. N. Am. Wildl. Nat. Res. Conf. 56,439-452.

13. Vieux, B. E., Freeman, G. E., LeDimet, E. and Guinepain, S. (1996) Hydrologic and sedimentation simulation in the prairie pothole region of North Dakota. Proc. N.D. Acad. Sci. 50.

14. Detenbeck, N. E., Elonen, C. and Taylor, D. L. (1996) Spatial and temporal variability of water quality of wetlands in the Woodworth Study Area. Proc. N.D. Acad. Sci. 50.

15. Wrubleski, D. (1996) Chironimidae (Diptera) of the Woodworth Study Area, North Dakota. Proc. N.D. Acad. Sci. 50.

16. Poulton, B. C. (1996) Effects of two fire suppressant foams on benthic invertebrates colonizing artificial substrates in portable limnocorrals. Proc. N.D. Acad. Sci. 50.

17. Vyas, N. B., Spann, J. W. and Hill, E. F. (1996) Effects of Silv-Ex on terrestrial wildlife. Proc. N.D. Acad. Sci. 50.

STATISTICS and APPLICATIONS

A Symposium Organized by: **Peter Thompson**
Department of Statistics, North Dakota State University

In affilliation with ASA Red River Valley Chapter

Friday, 26 April, 1996 Valley City, North Dakota

A *forum* for a diverse collection of North Dakota area statistics professionals to present current applied statistical research to an audience of their peers.

9:20 BEATING LUMP SUM DOLLAR-COST AVERAGING with AVERAGE DOLLAR-COST AVERAGING
Peter Thompson* and Min Fu, Statistics, North Dakota State University, Fargo

9:45 CHAOS THEORY in STATISTICAL ANALYSIS of TIME SERIES DATA
Kathy M Kraft*, Wei Ouyang, Diane L Larson, Mathematics, Jamestown College and Northern Prairie Science Center, Jamestown

10:40 p-VALUE MEASURES of TEST STATISTICS
Lorrie Lendvoy*, Statistics, North Dakota State University, Fargo

11:05 CONSTRUCTION of CONFIDENCE INTERVALS for the DIFFERENCE in DUPLICATE LABORATORY TEST RESULTS
Ariyaratna M Wijetunga*, Christine E McLaren, John A Koepke, Mathematics, Moorhead State University, Moorhead MN and Hospital Laboratories, Duke University Medical Center, Durham, NC

11:30 A SMALL SAMPLE SIGNAL-to-NOISE CORRECTED CONSISTENT MODEL SELECTION CRITERION
Allan McQuarrie*, North Dakota State University, Fargo

BEATING LUMP SUM DOLLAR-COST AVERAGING WITH AVERAGE DOLLAR-COST AVERAGING

by Peter Thompson* and Min Fu

A new investment strategy for lump sums is introduced, average dollar-cost averaging (ADCA). Mathematically, ADCA is shown to beat standard dollar-cost averaging (DCA) when uncorrelated period to period returns are assumed in the sense that ADCA has the same expected return as DCA but has less risk. ADCA and DCA are also compared using S&P 500 and T-bill data from 1926 to 1992. As predicted mathematically, ADCA dominates DCA on this historical data.

1. INTRODUCTION

Although commonly recommended by financial planners, dollar-cost averaging of lump sums (DCA) has been criticized for providing poor expected returns relative to an all-in-the-market strategy. Williams and Bacon [3] showed that historically, if one invested an entire lump sum in an S&P 500 index fund (with no expenses), nearly two thirds of the time one would out-perform a DCA strategy out of 90 day T-bills into the above S&P 500 index fund. The time period considered by William and Bacon was 1926 to 1991.

In spite of the lower expected return of the DCA strategy, it continues to be recommended because it has much lower risk associated with it than an all-in-the-market strategy. The purpose of this paper is to present a third investment strategy, average dollar-cost averaging (ADCA), and compare this to DCA. It will be shown that mathematically ADCA has an edge over DCA when uncorrelated period to period returns are assumed because it has the same expected return at less risk. The same historical data used by Williams and Bacon will be used to compare ADCA and DCA and the results will be shown to agree with the earlier mathematical results. Consequently, on a practical level, DCA is inferior to ADCA for lump sums.

Structurally this paper starts with a description of ADCA. Theoretical comparisons are then made between DCA and ADCA. Finally, DCA and ADCA are compared using historical data.

AVERAGE DOLLAR COST AVERAGING

With the usual DCA, the proportion of the lump sum in the market the first period is 1/n. The proportion in the second period is 2/n and so on. All will be in the market in the n^{th} period. If Π is a permutation of the integers 1 through n, we could choose to have 1/n of the lump sum in period $\Pi(1)$, 2/n of the lump sum in period $\Pi(2)$ and so on. This investment strategy would equivalent to standard DCA in terms of expected return and risk if we assume that the market behaves independently from period to period.

With average dollar-cost averaging (ADCA) we theoretically divide the lump sum into n! parts. Each part is then dollar-cost averaged into the market using a different permutation of the integers 1 through n. We will look at a few examples.

Case 1: n=2

We wish to invest a lump sum of 1 unit in 2 time periods. Using ADCA, we break the lump sum into 2!=2 parts and each part into 2 portions. We then DCA in each part using a different permutation. Define R_i to be the return in the i^{th} period. That is,

$$R_i = \frac{\textit{price at the end of the } i^{th} \textit{ period}}{\textit{price at the beginning of the } i^{th} \textit{ period}}.$$

The details of ADCA for this case are given in Table 1.

Case 2: n=3

We wish to invest a lump sum of 1 unit in 3 time periods. Using ADCA, we break the lump into 3!=6 parts and each part into 3 portions. We then DCA in each part using a different permutation. Details are given in Table 2.

We will look at an example for this case, where n=3. Suppose that we average dollar-cost average a lump sum of $18,000 into a stock over 3 time periods, and the price of the stock behaves as in Table 3. Then using our previous table we could get what is shown in Table 4.

Clearly, as n gets large it is impractical to create tables. However, the only information needed from the tables to compare A_{ADCA} with DCA will be A_{ADCA}, the total amount accumulated at the end of n periods. We will give a formula for A_{ADCA} but first we introduce some notation.

$$\text{Let} \quad G_{1,n}(R_1,\ldots,R_n)=\frac{\sum_{i=1}^{n}R_i}{n},$$

$$G_{2,n}(R_1,\ldots,R_n)=\frac{\sum_{i<j}R_iR_j}{\binom{n}{2}},$$

$$G_{3,n}(R_1,\ldots,R_n)=\frac{\sum_{i<j<k}R_iR_jR_k}{\binom{n}{3}},$$

$$\ldots,$$

$$G_{n,n}(R_1,\ldots,R_n)=R_1,R_2,\ldots,R_n.$$

In general, $G_{k,n}(R_1,\ldots,R_n)$ is the average of all products $R_{k_1}R_{k_2}\ldots R_{k_k}$ where $K_1<K_2<\ldots<K_k$.

It is easy to see by averaging out A_{DCA} over all permutations that:

$$A_{ADCA}=\frac{1}{n}G_{1,n}+\frac{1}{n}G_{2,n}+\ldots+\frac{1}{n}G_{n,n}$$

Other information given in the table that would be needed if we were to use ADCA in practice would be the amount of original units to have in and out of the market in the i^{th} period.

Clearly,
$A_{ADCA}(R_1,\ldots,R_{i-1},1,1,\ldots,1)$ =total accumulation after i-1 periods,
$A_{ADCA}(R_1,\ldots,R_{i-1},0,1,\ldots,1)$ =total amount out of the market in the i^{th} period,
and
$A_{ADCA}(R_1,\ldots,R_{i-1},1,1,\ldots,1)-A_{ADCA}(R_1,\ldots,R_{i-1},0,1,\ldots,1)$ will be the amount invested in the market in the i^{th} period.

Despite the apparent simplicity of the formulas here, for n>5 or so, a computer is needed. For example, when n=12, $G_{6,12}(R_1,\ldots,R_{12})$ involves the sum of $\binom{12}{6}=924$ terms, each of which is itself a product of 6 terms.

THEORETICAL COMPARISON BETWEEN DCA AND ADCA

First, we make some intuitive observations about the differences between DCA and ADCA. Since using DCA involves having almost everything invested for the last few periods and very little invested for the first few periods, DCA does well if losses in the market occur early, gains occur late. For ADCA, it doesn't matter what order the losses and gains come in, only magnitudes. We look at an example in Table 5.

The example in Table 5 points out that ADCA irons out the variability of DCA which is due to the order in which the ups and downs occur in the market. The example also points out how ADCA can generate profit out of "thin air" by taking advantage of volatility in the market.

Next, we take a theoretical look at DCA and ADCA. We will assume that the R_i defined before all have the same mean and variance and are uncorrelated. We will let Π denote a permutation, and A_{DCA_π} denote the total accumulation one would get dollar-cost averaging using the permutation Π.

First, we note that:

$$E(A_{ADCA})=\frac{1}{n!}\sum_{\pi}E(A_{DCA_\pi})$$
$$EA_{DCA}$$

Thus ADCA and DCA have the same expected accumulation amount and consequently the same expected total return.

Next, the risk of an investment procedure is typically measured by its variance. The smaller the variance, the less the risk, and the better the procedure. We get:

$$Var(A_{ADCA})=\left(\frac{1}{n!}\right)^2 Var\sum_{\pi}A_{DCA_\pi}$$
$$=\left(\frac{1}{n!}\right)^2 Var\sum_{\pi}A_{DCA_\pi}+\sum_{\pi_1\neq\pi_2}Cov(A_{DCA_{\pi_1}},A_{DCA_{\pi_2}})$$
$$<\left(\frac{1}{n!}\right)^2\left[n!VarA_{DCA}+n!(n!-1)VarA_{DCA}\right]$$
$$=Var(A_{DCA}).$$

Thus, ADCA and DCA have the same expected return but the variance of ADCA is less than that of DCA.

A natural question is by how much the variance of ADCA will beat that of DCA. In general, this is very hard to answer as the variance calculations are extremely complicated. We look at a very simple example.

Example: Have n=2. If we assume $E(R_i)=1.1,\quad Var(R_i)=(.2)^2=.04,$ we have:

$$A_{DCA}=\left(\frac{1}{2}\right)(R_1R_2+R_2),$$

$$A_{ADCA}=\left(\frac{1}{2}\right)\left[R_1R_2+\frac{1}{2}(R_1+R_2)\right],$$

$$Var(A_{DCA})=E\left[\frac{1}{2}(R_1R_2+R_2)\right]^2-\left[E\left(\frac{1}{2}(R_1R_2+R_2)\right)\right]^2$$

$$Var(A_{DCA})=E\left[\frac{1}{2}(R_1R_2+R_2)\right]^2-\left[E\left(\frac{1}{2}(R_1R_2+R_2)\right)\right]^2$$

$$=\frac{1}{4}E\left(R_1^2R_2^2+2R_1R_2^2+R_2^2)\right)-\frac{1}{4}\left[E(R_1R_2+R_2)\right]^2$$

$$=\frac{1}{4}\Big[\left((1.1)^2+.04\right)\left((1.1)^2+.04\right)$$

$$+2(1.1)\left((1.1)^2+.04\right)+(1.1)^2+.04\Big]$$

$$-\frac{1}{4}\left[(1.1)(1.1)+(1.1)\right]^2$$

$$=.0566.$$

$$Var(A_{DCA})=Var\left[\frac{1}{2}\left(R_1R_2+\frac{1}{2}(R_1+R_2)\right)\right]$$

$$=Var\left[\frac{1}{2}\left(R_1R_2+\frac{1}{2}(R_1+R_2)\right)+\frac{1}{8}\right]$$

$$=Var\left[\frac{1}{2}(R_1+.5)(R_2+.5)\right]$$

$$=\frac{1}{4}\left\{E(R_1+.5)^2(R_2+.5)^2-\left[E(R_1+.5)(R_2+.5)\right]^2\right\}$$

$$=\frac{1}{4}\left[\left((1.1)^2+.04+1.1+.25\right)^2-(1.6)^4\right]$$

$$=.0516.$$

Since $\frac{.0516}{.0566}=.91,$ we have about a 9% reduction in variance.

In the example looked at earlier in this section, $R_1R_2R_3=1$. In some of the cases DCA made money, in some of the cases DCA lost money. ADCA made money in all the cases we looked at. We will now prove that this will always be the case when $\Pi R_i=1$, unless $R_i=1$ for all i.

Suppose $\Pi R_i=1$, then

$$A_{ADCA}=\frac{1}{n}\left[G_{1,n}+G_{2,n}+...+G_{n,n}\right]$$

$$=\frac{1}{n}\left[\frac{\sum_{i=1}^{n}R_i}{n}+\frac{\sum_{i<j}R_iR_j}{\binom{n}{2}}+\frac{\sum_{i<j<k}R_iR_jR_k}{\binom{n}{3}}+...+R_1R_2R_3...R_n\right]$$

We know that $\frac{R_1+R_2+R_3+...+R_n}{n}\geq\sqrt[n]{\prod_i R_i}$, and that the left side is equal to the right side only when all R_i are equal. So when $R_1R_2R_3...R_n=1$, we get that $\frac{R_1+R_2+R_3+...+R_n}{n}>1$; the same is true for other terms in A_{ADCA}. For example, if not all $R_i=1$ then, $\frac{\sum_{i<j}R_iR_j}{\binom{n}{2}}>\sqrt[\binom{n}{2}]{\prod_{i<j}R_iR_j}=$

$$\sqrt[\binom{n}{2}]{(R_1R_2)(R_1R_3)...(R_1R_n)(R_2R_3)(R_2R_4)...(R_2R_n)...(R_{n-1}R_3R_n)}$$

$$=\sqrt[n]{(R_1R_2R_3...R_n)^{n-1}}=1,\text{ when }R_1R_2R_3...R_n=1.$$

Consequently,

$$A_{ADCA}=\frac{1}{n}\left[\frac{\sum_{i=1}^{n}R_i}{n}+\frac{\sum_{i<j}R_iR_j}{\binom{n}{2}}+\frac{\sum_{i<j<k}R_iR_jR_k}{\binom{n}{3}}+...+R_1R_2R_3...R_n\right]>1$$

when $R_1R_2R_3...R_n=1$ and not all R_i are equal to 1. $A_{ADCA}>1$ means that some profit is made.

COMPARISON AMONG ALL-IN-THE-MARKET, DCA AND ADCA USING ACTUAL MARKET RETURN DATA

In this section, the historical data is the monthly total rates of return for the Standard & Poor's 500 Stock index (S&P 500) and 90-day Treasury bill from 1926 and 1992 as reported in Ibbotson Associates' 1993 Yearbook [2]. We took every consecutive 12 months as a one investment year so that we had 66*12+1=793 investment years to compare instead of 67 years (1992-1926). The comparisons are average annual return and variance or standard deviation between three investment methods: All-in-the-market (ALLM) which put all the money into the market at the beginning of each investment year, DCA and ADCA.

In the cases of using DCA and ADCA, we put nonactively invested money into the Treasury bills (T-bills). T-bills have essentially no risk. Thus, our total accumulation of return for DCA and ADCA needed to be altered to take into account the T-bill earnings.

In the DCA case, we start by putting 1/12 of the money into the S&P 500 and the remaining 11/12 into T-bills. At the beginning of the second period, we put another 1/12 plus the corresponding interest earned by this 1/12 portion's T-bill interest into the S&P 500; we keep doing this until all the money is invested in the stock market at the beginning of last period.

In the ADCA case, we define $N_i = \frac{R_i}{F_i}$, where $F_i = 1+$monthly return on a T-bill purchased at the start of the i_{th} month and N_i is essentially 1 plus the net return above the guaranteed return over the same time period. We can get a total accumulation

$$A_{ADCA} = (F_1F_2F_3 \ldots F_n)\left(\frac{1}{n}\right)\left[\frac{\sum_{i=1}^{n} N_i}{n} + \frac{\sum_{i<j} N_iN_j}{\binom{n}{2}} + \frac{\sum_{i<j<k} N_iN_jN_k}{\binom{n}{3}} + \ldots + N_1N_2N_3 \ldots N_n\right].$$

For simplicity, we don't introduce L, the amount of the lump sum, into our comparison. Table 6 shows the results. Fu [1] shows details of the computer work needed.

In Table 6, the ALLM provided a 12.6% return rate while DCA provided a 8.5% return rate, which is almost the same rate as ACDA. So, among the three ALLM beat the other two in the average annual return while DCA and ADCA stood at the same level. Speaking to risk, the ADCA beat the other two with a 12% standard deviation while DCA had 13.1% and the worst, ALLM had 22.5%. This is in agreement with what we'd have predicted beforehand.

We also looked at what percent of the time the various methods turned a profit. The results are in Table 7. Again, ADCA was slightly "less risky" than DCA which was "less risky" than ALLM.

As one final measure of risk we calculated that in 459 of the 793 investment years (58%), ADCA generated a return closer to 8.5% than DCA did.

Finally, we looked at what would happen in the money was divided between ALLM and ADCA in such a way as to get the same standard deviation as DCA but a higher average return. We found that with 10.7% in ALLM and 89.3% in ADCA we'd have had an average return of 8.92% with a standard deviation equal to that of DCA.

CONCLUSION

We would conclude that DCA of lump sums in not an ideal way to cut risk. ADCA ties it return-wise and beats it slightly risk-wise. This should not be taken as a whole-hearted endorsement of ADCA. ADCA suggested itself mathematically as being superior to DCA. Other simpler but similar methods may be better than ADCA on a practical level.

REFERENCES

1. Fu, Min, "Beating Lump Sum Dollar Cost Averaging with Average Dollar Cost Averaging", master's paper, North Dakota State University, 1995.
2. Ibbotson, Roger G. and Sinquefied, Rex A., "Stocks, Bonds, Bills and Inflation 1993 Yearbook", (Chicago: Ibbotson Associates).
3. Williams, Richard E. and Bacon, Peter W., "Lump Sum Beats Dollar-Cost Averaging", Journal of Financial Planning, April 1993.

Table 1: ADCA n=2

	Permutation (1,2)	Permutation (2,1)	Total
Proportion of the portions in the market in the 1st Period	$\frac{1}{2}$	1	$\frac{3}{4}$
Proportion of the portions in the market in the 2nd Period	1	$\frac{1}{2}$	$\frac{3}{4}$
Units in the market in the 1st period	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
Units out of the market in the 1st period	$\frac{1}{4}$	0	$\frac{1}{4}$
Units in the market in the 2nd period	$\frac{1}{4}R_1+\frac{1}{4}$	$\frac{1}{4}R_1$	$\frac{1}{2}R_1+\frac{1}{4}$
Units out of the market in the 2nd period	0	$\frac{1}{4}R_1$	$\frac{1}{4}R_1$
Value after 2nd period	$\frac{1}{4}R_1R_2+\frac{1}{4}R_2$	$\frac{1}{4}R_1R_2+\frac{1}{4}R_1$	$\frac{1}{4}(R_1+R_2)+\frac{1}{2}(R_1R_2)$

Table 2: ADCA n=3

	Permutation (1,2,3)	Permutation (1,3,2)	Permutation (2,1,3)	Permutation (2,3,1)	Permutation (3,1,2)	Permutation (3,2,1)	Total
Prop. of the portions in the market in the 1st Period	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{2}{3}$	1	$\frac{2}{3}$	1	$\frac{2}{3}$
Prop. of the portions in the market in the 2nd Period	$\frac{2}{3}$	1	$\frac{1}{3}$	$\frac{1}{3}$	1	$\frac{2}{3}$	$\frac{2}{3}$
Prop. of the portions in the market in the 3rd Period	1	$\frac{2}{3}$	1	$\frac{2}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{2}{3}$
Units in the market in the 1st Period	$\frac{1}{18}$	$\frac{1}{18}$	$\frac{2}{18}$	$\frac{3}{18}$	$\frac{2}{18}$	$\frac{3}{18}$	$\frac{2}{3}$
Units out of the market in the 1st Period	$\frac{2}{18}$	$\frac{2}{18}$	$\frac{1}{18}$	0	$\frac{1}{18}$	0	$\frac{1}{3}$
Units in the market in the 2nd Period	$\frac{1}{18}+\frac{1}{18}R_1$	$\frac{2}{18}+\frac{1}{18}R_1$	$\frac{1}{18}R_1$	$\frac{1}{18}R_1$	$\frac{1}{18}+\frac{1}{18}R_1$	$\frac{2}{18}R_1$	$\frac{4}{18}+\frac{8}{18}R_1$
Units out of the market in the 2nd Period	$\frac{1}{18}$	0	$\frac{1}{18}+\frac{1}{18}R_1$	$\frac{2}{18}R_1$	0	$\frac{1}{18}R_1$	$\frac{2}{18}+\frac{4}{18}R_1$
Units in the market in the 3rd Period	$\frac{1}{18}+\frac{1}{18}R_2$ $+\frac{1}{18}R_1R_2$	$\frac{1}{18}R_2+\frac{1}{18}R_1R_2$	$\frac{1}{18}+\frac{1}{18}R_1$ $+\frac{1}{18}R_1R_2$	$\frac{1}{18}R_1+\frac{1}{18}R_1R_2$	$\frac{1}{18}R_1R_2$	$\frac{1}{18}R_1R_2$	$\frac{2}{18}+\frac{2}{18}R_1+\frac{2}{18}R_2$ $+\frac{6}{18}R_1R_2$
Units out of the market in the 3rd Period	0	$\frac{1}{18}R_1$	0	$\frac{1}{18}R_1$	$\frac{1}{18}R_2+\frac{1}{18}R_1R_2$	$\frac{1}{18}R_2+\frac{1}{18}R_1R_2$	$\frac{2}{18}R_1+\frac{2}{18}R_2+\frac{6}{18}R_1R_2$
Value after the 3rd Period	$\frac{1}{18}R_3+\frac{1}{18}R_2R_3$ $+\frac{1}{18}R_1R_2R_3$	$\frac{1}{18}R_2+\frac{1}{18}R_2R_3$ $+\frac{1}{18}R_1R_2R_3$	$\frac{1}{18}R_3+\frac{1}{18}R_1R_3$ $+\frac{1}{18}R_1R_2R_3$	$\frac{1}{18}R_1+\frac{1}{18}R_1R_3$ $+\frac{1}{18}R_1R_2R_3$	$\frac{1}{18}R_2+\frac{1}{18}R_1R_2$ $+\frac{1}{18}R_1R_2R_3$	$\frac{1}{18}R_1+\frac{1}{18}R_1R_3$ $+\frac{1}{18}R_1R_2R_3$	$\frac{2}{18}(R_1+R_2+R_3)+$ $\frac{2}{18}(R_1R_2+R_1R_3+R_2R_3)$ $+\frac{6}{18}R_1R_2R_3$

Table 3: ADCA Example n=3

Time	Price	R value
Start	$10	
End of 1st Period	$20	R_1=2.00
End of 2nd Period	$15	R_2=0.75
End of 3rd Period	$20	R_3=4/3

Table 4: Results of ADCA Example n=3

Time Period	Invested	Value at the end of Period	Non Invested	Value at the end of Period	Total Value at the end of Period
1st Period	$12,000	$24,000	$ 6,000	$ 6,000	$30,000
2nd Period	$18,000	$13,500	$12,000	$12,000	$25,500
3rd Period	$16,500	$22,000	$ 8,500	$ 8,500	$30,500

Table 5: Example of Comparison between DCA and ADCA

	Share Price				End Value of $1,000	End Value of $1,000
R_1 R_2 R_3	Start Period 1	Start Period 2	Start Period 3	End	Initial Investment Using DCA	Initial Investment Using ADCA
.2 1 5	$10	$ 2	$ 2	$10	$3,667	$1,711
.2 5 1	$10	$ 2	$10	$10	$2,333	$1,711
1 .2 5	$10	$10	$ 2	$10	$2,333	$1,711
1 5 .2	$10	$10	$50	$10	$ 733	$1,711
5 .2 1	$10	$50	$10	$10	$ 733	$1,711
5 1 .2	$10	$50	$50	$10	$ 467	$1,711

Table 6: Average Annual Return Comparison among ALLM, DCA & ADCA

Method	ALLM	DCA	ADCA
Average Annual Return	0.126446	0.084727	0.084740
Standard Deviation of the Return	0.224907	0.130981	0.119886
Maximum Return	1.628764	0.686578	0.811678
Minimum Return	-0.675760	-0.503530	-0.413190

Table 7: The Number of Earning Years Various Strategies Make a Profit

Performance	Made Profit	Lost Money	% Where Profit Was Made
ALLM	575	218	72.5%
DCA	610	183	76.9%
ADCA	626	167	78.9%

CHAOS THEORY IN STATISTICAL ANALYSIS OF TIME SERIES DATA

Kathy M. Kraft,* Wei Ouyang, and Diane L. Larson
Mathematics Department, Jamestown College, Jamestown, ND 58405 (KMK,WO)
Northern Prairie Science Center, Jamestown, ND 58401 (DLL)

We review methods for determining chaos in short time series data. We have time series data of counts of several bird species over 66 years. This time series is relatively short, noisy (there is a random component), multi-dimensional and nonstationary. There has been research on short, noisy time series but most work has been on either low noise data, one-dimensional data, or stationary data, and these methods have been tested on limited data sets.

The detection of chaos in deterministic dynamical systems is well established, but there are numerous examples of data, such as time series for biological systems, which include a random component (i.e., noisy time series). If a noisy time series has a large number of observations (perhaps even more than 1000), then there are some methods that may detect chaos in the system. But with a short time series, the detection of even a pattern in a time series, much less chaos, may be difficult. We review several methods that have been developed to detect chaos in short time series.

We wish to determine whether a short time series of bird counts are chaotic. The bird counts were done once a year for 66 years for several species and were thought to be related to northern hemisphere weather indices. Various weather time series have shown evidence of being chaotic. Thus, it is hypothesized that the weather indices may also exhibit chaos and, in turn, the bird counts. Using established time series methods, for some species, we were unable to model the time series. Some of the time series may be random, but what seems to be random time series may actually be chaotic. The modeling did give evidence that the data are not stationary. The data are measurements of one variable (number of birds) over time and yet this variable is most likely related to other variables that may be unknown or at least unmeasured. The number of these variables is called the dimension and the dynamical system of bird counts is multi-dimensional.

In a chaotic system, data show extreme sensitivity to initial conditions. So, two time series measuring the same variable may look almost identical, but then, at some point, diverge radically. Unfortunately, the time series for chaotic data may be similar to time series for noisy data or a deterministic system with random noise added. If the time series is determined completely by equations, then there are established methods for detecting chaos.

Each variable in a multi-dimensional system has a Lyapunov exponent (LE) which measures the exponential rate of divergence of time series. If the largest LE in the system is positive, then the system is chaotic. With only one measured variable, it appears that the largest LE in a system could not be found, but Taken's theorem (1) shows that some properties of the multi-dimensional system may be reconstructed using one variable as long as there are enough data points. The LE may be used to detect chaos in a system and does not change even if the data are noisy, so no model need be found. But, to calculate the LE you must either know the equations that determine the system or you must have a very large number of observations for an estimate.

Far fewer studies have been done on methods for detecting chaos in a time series that is not deterministic. One method used for biological data is to model the time series data and detect chaotic behavior based on this model, considering the data to be deterministic. But this method is model dependent. If another model were chosen for the same set of data, the results could be completely different.

Nonparametric methods have been proposed to detect chaos for short, noisy time series but have only been tested on a small number of data sets with known properties. Wolff (2) developed a Local Lyapunov exponent (LLE) which takes an average divergence over a region of the system. This method is simple but it was developed using a one-dimensional system and may not generalize to a multi-dimensional problem. Nychka et al. (3) introduced a nonparametric regression technique to estimate LEs that may work for short time series. This method was tested on a small number of known systems which have low noise and low dimension. A method introduced by Ellner and Turchin (4) looks promising for very short time series (20-50 data points) like the bird count data, but it requires that the time series is stationary; it too has only been tested on low dimensional data. The methods listed may all be appropriate for the bird count data, but because the methods have been tested only on a restricted number of known systems, any conclusions for our data set would be unreliable. We propose further study of these methods on other data sets with known properties and some theoretical work that may clarify the uses of these methods.

References

1. Hastings, A., Hom, C.L., Ellner, S., Turchin, P., Godfrey, H.C.J. (1993). Chaos in ecology: Is mother nature a strange attractor? Annu. Rev Ecol Syst 24:1-33.
2. Wolff, R.C.L.(1992) Local Lyapunov exponents: Looking closely at chaos. J R Statist Soc B. 54:353-371.
3. Nychka, D., Ellner, S., Gallant, A.R., McCaffrey, D. (1992) Finding chaos in a noisy systems. J R Statist Soc B 54:399-426.
4. Ellner, S. and Turchin, P. (1995) Chaos in a noisy world: New methods and evidence from time-series analysis. The American Naturalist. 145:343-375.

P-VALUE MEASURES OF TEST STATISTICS

by Lorrie Lendvoy

In hypothesis testing situations, it is customary for p-values to be reported. Thus, before collecting data, it is only natural to look into what sort of p-value one might expect "on average" for the particular test statistic one is using.

In this paper, mean, median and .75 quantile p-values are discussed. Charts are then given for a noncentral χ^2 and a noncentral F testing situation.

Power and p-Values:

The power of a test is the probability of rejecting the null hypothesis, H_0, at a predetermined significance level α. The power can be calculated before observing data and is some value between 0 and 1.

Since we want to reject a false null hypothesis, we would like the power to be as close to 1 as possible in that situation. With that in mind, we try to choose test statistics efficiently and choose sample sizes appropriately.

The p-value for a test statistic is the probability of getting data at least as extreme (as measured by the statistic) as the actual observed data under the assumption that H_0 is true. Before observing data, the p-value is a random variable which takes values between 0 and 1. Once data is observed the p-value is calculated. It is desirable for the p-value to be close to 0 when H_0 is false.

Keeping in mind that the p-value is a random variable, we look at three different ways of describing its typical behavior. The expected p-value is what the average p-value would zero in on if the test were run repeatedly. The median p-value is the value for which the p-value has a 50% chance of being smaller than. The .75 quantile p-value is the value the p-value has a 75% chance of being less than.

Some Relationships:

Test statistics with very high power will tend to have very low expected and median p-values and vice versa. When the power is .5, the median p-value is α. When the power is .75, the .75 quantile p-value is α.

If, as is often the case, a p-value will be reported rather than just an accept/reject decision, it seems reasonable that a p-value measure of a test statistic is preferable to power values. Also, since p-values are random variables which take values between 0 and 1 and which ideally tend to be close to 0 when H_0 is false, they tend to have an extremely skewed distribution when H_0 is false. Consequently, the median p-value tends to be much smaller than the mean p-value and is arguably a better measure of its behavior as a random variable. It is also not unusual for the .75 quantile p-values to be less than the expected p-value.

We demonstrate some of these ideas with an example where the equality of three means is tested.

Example:

Suppose that $Y_{11}, Y_{12}, \ldots, Y_{1N}, Y_{21}, \ldots, Y_{2N}, Y_{31}, \ldots, Y_{3N}$ are independent, $Y_{ij} \sim Normal(\mu_i, \sigma^2)$. We want to test $H_0: \mu_1 = \mu_2 = \mu_3$ vs. $H_1: H_0$ is false. We proceed in the usual way, first looking at the situtation where σ^2 is known, then where σ^2 is unknown.

Case 1: σ^2 is known.

Let $\chi^2 = \dfrac{N\sum_{i=1}^{3}(Y_{i.} - Y_{..})^2}{\sigma^2}$. We report the p-value

$$p(\chi^2) = \mathrm{P}\left(\chi^2(2) > \chi^2\right) = e^{-\frac{\chi^2}{2}}.$$

When H_0 is false, $\chi^2 \sim Noncentral\, \chi^2(2,\lambda)$, where $\lambda = \dfrac{N\sum_{i=1}^{3}(\mu_i - \overline{\mu})^2}{\sigma^2}$. A calculation gives:

$$E\left[p(\chi^2)\right] = \frac{1}{2}e^{-\frac{\lambda}{4}}.$$

We use SAS [1] to find median and .75 quantile p-values. Information about the behavior of the p-values is given in Chart 1.

As an example, suppose we desire a median p-value of .02 when we have $\mu_1 = \mu,\ \mu_2 = \mu,\ \mu_3 = \mu + \sigma$. From Chart 1, we need $\lambda \approx 6.5$. Since $\frac{\sum_{i=1}^{3}(\mu_i - \overline{\mu})^2}{\sigma^2} = \frac{2}{3}$, we need $N\left(\frac{2}{3}\right) \approx 6.5$, thus we should take *N=10*.

Case 2: σ^2 is unknown.

Let $F = \frac{N\sum_{i=1}^{3}(Y_{i.} - Y_{..})^2 \Big/ 2}{\sum_{i=1}^{3}\sum_{j=1}^{N}(Y_{ij} - Y_{i.})^2 \Big/ 3(N-1)}$. We report the p-value $p\left(F\left(2,3(N-1)\right) > F\right)$. When H_0 is false, $F \sim Noncentral\ F(2,3(N-1),\lambda)$, where $\lambda = \frac{N\sum_{i=1}^{3}(\mu_i - \overline{\mu})^2}{\sigma^2}$. Again, we use SAS to find the median p-values. Information about the p-values is given in Chart 2.

As an example, suppose that again we desire a median p-value of .02 when we have $\mu_1 = \mu,\ \mu_2 = \mu,\ \mu_3 = \mu + \sigma$. Since as before $\frac{\sum_{i=1}^{3}(\mu_i - \overline{\mu})^2}{\sigma^2} = \frac{2}{3}$, from Chart 2, we get that we should take *N=11*.

References

1. SAS Institute, Inc. (1990). SAS/STAT User's Guide (Vol. 2). Cary, NC: SAS Institute.

Chart 1: p-Values - Noncentral $\chi^2\left(2, \lambda = N\frac{\sum_{i=1}^{3}(\mu_i - \overline{\mu})^2}{\sigma^2}\right)$

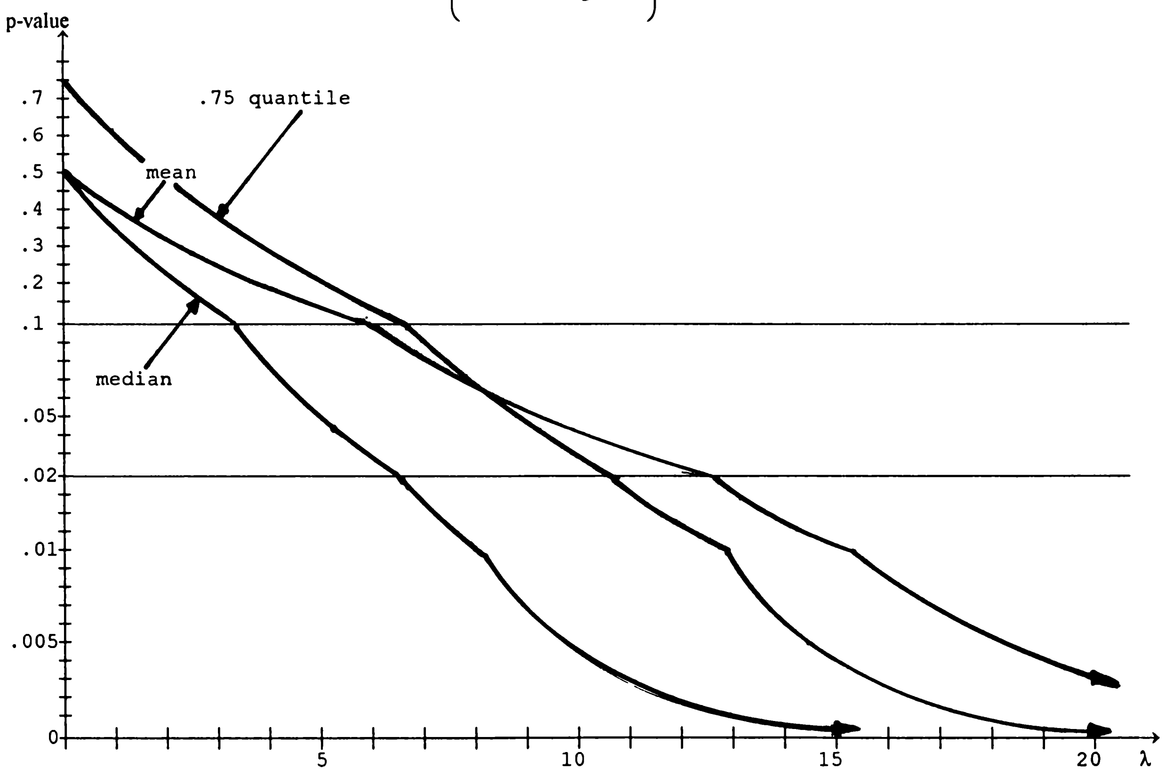
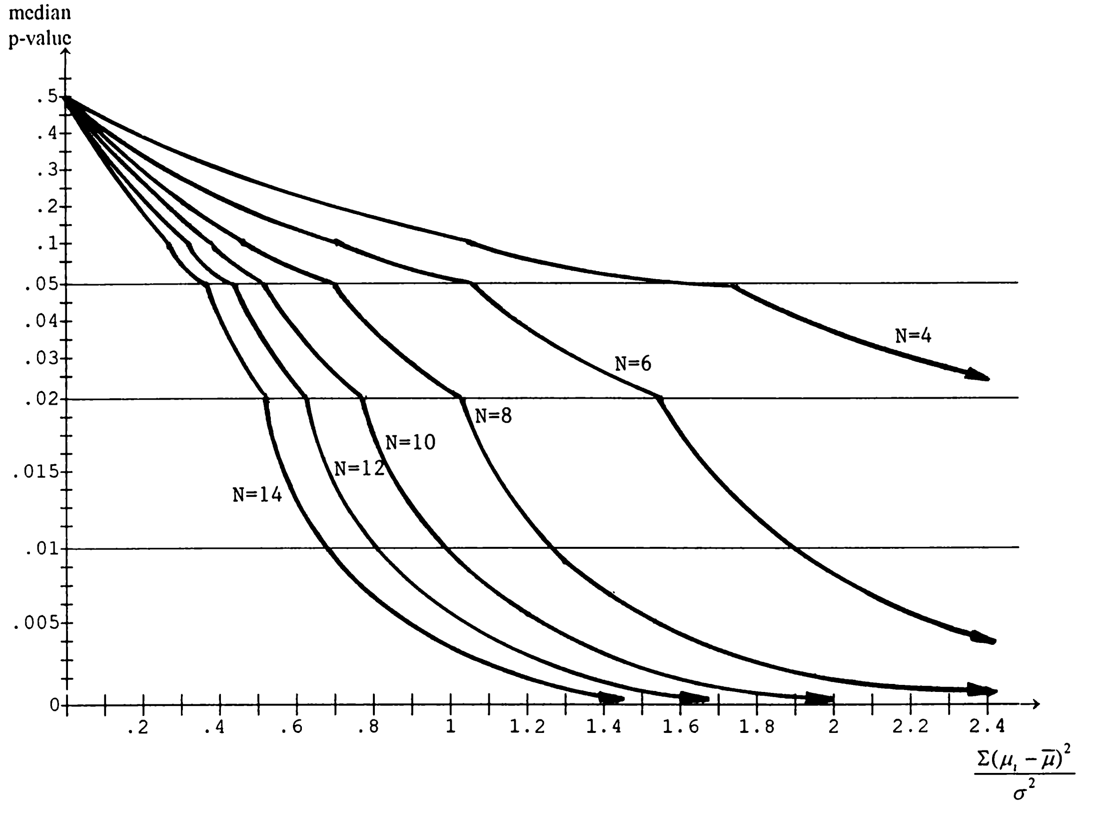


Chart 2: p-Values - Noncentral $F\left(2, 3(N-1), \lambda = N\frac{\sum_{i=1}^{3}(\mu_i - \bar{\mu})^2}{\sigma^2}\right)$



CONSTRUCTION OF CONFIDENCE INTERVALS FOR THE DIFFERENCE IN DUPLICATE LABORATORY TEST RESULTS

Ariyaratna M. Wijetunga*, Christine E. McLaren, John A. Koepke

Department of Mathematics, Moorhead State University, Moorhead, Mn, (A.W., C.M.) and Department of Hospital Laboratories, Duke University Medical Center, Durham, NC, (J.K.)

Abstract

The statistical theory underlying a statistical protocol we previously developed for evaluating the need for duplicate coagulation testing is presented. The results of an application of the protocol to duplicate prothrombin times and partial thromboplastin times are discussed.

Introduction

In coagulation laboratories, tests of blood coagulation such as the prothrombin time and partial thromboplastin time are often performed in duplicate. In the past, the reproducibility of these tests has been poor for a variety of reasons. These include the use of manual methods which are difficult to standardize, the variability of biological reagents, and other poorly controlled variables. The development of more sophisticated instruments which determine coagulation end points precisely has decreased the need for duplicate testing. Nevertheless, the perception that duplicate testing is still necessary has persisted in many laboratories. In fact, the code of Federal Regulations, Title 42 states:

" Tests such as the one stage prothrombin time test shall be run in duplicate unless the laboratory can demonstrate that low frequency of random error or high precision makes such testing unnecessary. [405.1317 Section b-5 (1 October 1981)]."

Although the CLIA '88 regulations have now superseded earlier versions, duplicate testing continues to be common. A number of papers have been published either upholding or decrying this practice (2 – 12). We previously developed a statistical protocol applicable to all coagulation testing systems (instrument coupled with reagent). This protocol consisted of statistical procedures that are appropriate to determine whether or not singlet testing of samples can be substituted for duplicate testing (5).

In this paper, we present the statistical theory underlying an important part of the protocol, that is, construction of exact confidence intervals for the mean and standard deviation of the absolute differences between the duplicate test results. Assuming that the differences between duplicate test results has a Gaussian distribution, we derive the distribution of the absolute difference and the confidence intervals for the parameters of this distribution. We illustrate the construction of these confidence intervals using data sets of prothrombin time and partial thromboplastin time.

Theory and methods

If coagulation tests are reproducible, then the scatter plots between the duplicate test results should show a linear relationship between duplicate coagulation times at various levels. Also, the true mean difference between the duplicate measurements should not be significantly different from zero. This can be established by constructing confidence intervals for the true mean difference of the duplicate measurements. We introduce, two parameters, the true mean and the standard deviation of the absolute differences between the duplicate measurements as measures of the precision of the instrument which is used to measure the coagulation times. If the coagulation tests are reproducible, the true mean and the standard deviation of the absolute differences between duplicate test results should be small. This can be examined by constructing exact confidence intervals for the said parameters. To construct these exact confidence intervals, the differences between duplicate measurements should be normally distributed with a mean of zero. This assumption can be tested with the Kolmogorov – Smirnov (K-S) test (6).

We now derive the distribution of the absolute differences of the duplicate test results. Let D be a random variable which describes the differences between the duplicate test results produced by a particular machine. We assume that D has a Gaussian distribution with mean μ and variance σ^2. The distribution of D is given by

$$f_D(y) = \frac{1}{\sqrt{2\pi}\ \sigma}\ e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2},$$

$$-\infty < y < \infty, \quad -\infty < \mu < \infty, \quad \sigma^2 > 0.$$

Let $X = | D |$. Then the cumulative distribution function of X

$$= 2 \int_0^x \frac{1}{\sqrt{2\pi}\ \sigma}\ e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2} dy .$$

Then, $E(X) = \frac{2\sigma}{\sqrt{2\pi}} e^{-\frac{1}{2}\frac{\mu^2}{\sigma^2}} +$

$$\int_{-\mu/\sigma}^{\infty} \frac{2\mu}{\sqrt{2\pi}}\ e^{-\frac{1}{2}u^2}\, du,$$

where $u = \frac{x-\mu}{\sigma}$, and

$$Var(X) = (\sigma^2 + \mu^2) - [\frac{2\sigma}{\sqrt{2\pi}} e^{-\frac{1}{2}\frac{\mu^2}{\sigma^2}} + \int_{-\mu/\sigma}^{\infty} \frac{2\mu}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} du]^2.$$

We assume the random variable D has mean $\mu = 0$. Then, the mean and variance of X can be written as

$$E(X) = E(|D|) = (\frac{2}{\sqrt{2\pi}})\sigma, \quad (1.1)$$

and

$$Var(X) = Var(|D|) = (1 - \tfrac{2}{\pi})\sigma^2. \quad (1.2)$$

Let D_i, i = 1, 2, 3, . . . , n be a random sample of n independent differences of duplicate measurements. Under the assumption that the differences of duplicate measurements have a normal distribution with mean zero, D_i/σ, i = 1, 2, . . ., n, can be considered as a random sample from the standard normal distribution. By using the facts that the square of a standard normal random variable has a chi-squared distribution with one degree of freedom (χ^2_1) and the sum of n independent chi-squared random variables with one degree freedom has a chi squared distribution with n degrees of freedom (χ^2_n), we get

$\sum_1^n D_i^2/\sigma^2$ has a chi Squared distribution with n

degrees of freedom. Therefore,

$$P[\sum_1^n D_i^2/\sigma^2 > \chi^2_{1-\alpha, n}] = 1 - \alpha,$$

where α is the upper tail probability of the chi-squared distribution with n degrees of freedom.

This gives

$$P[\sigma^2 < \frac{\sum_{i=1}^n D^2_i}{\chi^2_{1-\alpha,n}}] = 1 - \alpha \quad (1.3)$$

Now, by using (1.1),

$$P[0 < E(|D|) < \frac{2}{\sqrt{2\pi}}\sqrt{\sum_{i=1}^n D^2_i/\chi^2_{1-\alpha, n}}] = 1 - \alpha. \quad (1.4)$$

Similarly, again, by using the fact that $\sum_1^n D_i^2/\sigma^2$ has a Chi Square distribution with n degrees of freedom, we get

$$P[\chi^2_{1-\frac{\alpha}{2}, n} < \frac{\sum_1^n D_i^2}{\sigma^2} < \chi^2_{\frac{\alpha}{2}, n}] = 1 - \alpha,$$

and hence

$$P[(\sum_1^n D_i^2)/\chi^2_{\frac{\alpha}{2}, n} < \sigma^2 < (\sum_{i=1}^n D_i^2)/\chi^2_{1-\frac{\alpha}{2}, n}] = 1 - \alpha.$$

Therefore, by using (1.2), we get

$$P[(1 - \tfrac{2}{\pi})\frac{\sum_1^n D_i^2}{\chi^2_{\frac{\alpha}{2}, n}} < Var(|D|) < (1 - \tfrac{2}{\pi})\cdot \frac{\sum_1^n D_i^2}{\chi^2_{1-\frac{\alpha}{2}, n}}] = 1 - \alpha,$$

and

$$P[\sqrt{(1 - \tfrac{2}{\pi})\frac{\sum_1^n D_i^2}{\chi^2_{\frac{\alpha}{2}, n}}} < \sigma_{|D|} <$$

$$\sqrt{(1-\tfrac{2}{\pi})\frac{\sum_{1}^{n} D_i^2}{\chi^2_{1-\frac{\alpha}{2},\,n}}}\;] = 1-\alpha, \qquad (1.5)$$

where $\sigma_{|D|} = \sqrt{Var(|D|)}$

Equations (1.4) and (1.5) are used to compute $100(1-\alpha)\%$ confidence intervals for the mean and the standard deviation of the differences between the duplicate measurements under consideration.

Data

Data sets for analysis were selected from laboratory log books. The data collected are the prothrombin times and partial thromboplastin times done in duplicate using a commercial coagulation instrument. First, an overall estimate of the usual clinical span of coagulation times was made for both tests. Then this range was divided into 4 quartiles, and 32 duplicate determinations were collected so that each quartile would have 8 observations. Since the majority of tests are in the normal or minimally abnormal range, the lower quartiles were completed promptly whereas the fourth quartile required a large number of specimens before eight duplicate sets were found. This method of obtaining the data was devised to make sure that the data cover a wide range of measurements. The actual observations can be found in (5).

Results

The details of the complete application of the protocol can be found in (5). In this paper, we will only outline the results for illustrative purposes. There are 32 observations in each data set. The scatter plots between the duplicate test results showed that the relationship is linear and the regression analysis showed that this linear relationship is not significantly different from the line of identity (p=0.384 for prothrombin time and p= 0.583 for partial thromboplastin time). The K-S test showed no significant difference from a normal distribution with mean of zero (p-value for prothrombin time lies between .10 and .15 and it is greater than 0.2 for partial thromboplastin time). This result validates the underlying assumption for construction of confidence intervals for the mean and standard deviation of absolute differences. Also the mean of the differences of the duplicate test results was not significantly different from zero for the prothrombin times and the partial thromboplastin times.

A one-sided 95% confidence interval for the mean of absolute differences of prothrombin times was (0.0s, 0.17s), and for the partial thromboplastin times, it was (0.0s, 1.99s). A 95% two-sided confidence interval for the standard deviation of the absolute differences of the prothrombin times was (0.13s, 0.22s), and for partial thromboplastin times, it was (1.59s, 2.61s)

Summary

We propose that the standard deviation of the absolute difference between the duplicate measurements, $\sigma_{|D|}$, is a reasonable measure of the

precision of a coagulation instrument. Necessarily, an instrument with a smaller $\sigma_{|D|}$ will measure more precisely. Since the two parameters, the mean and the standard deviation of the absolute differences of the test results, are related, the standard deviation, which measures the variability, would be a sufficient measure. By examining the confidence intervals we obtained for $\sigma_{|D|}$ for the two cases, it seems that the partial thromboplastin times may be more problematic with coagulation testing and therefore duplicate testing may continue to be required for some instruments.

References

1. Sage-el, A., Burns, E., and Wenz, B.: The unwarranted use of replicate analysis in routine coagulation studies. Am J Clin Pathol 83:81-83, 1985.
2. Kramer, G., and Bradlow, B.A.: An analysis of duplicate testing of prothrombin time and activated partial thromoplastin time. Am J Clin Pathol 95: 77-81, 1991.
3. Koepke, J.A.: Duplicate coagulation testing - Management Tech Sample No. 3MGMT-4. American Society of Clinical Pathologists. Chicago, IL 1984.
4. Koepke, J.A.: Duplicate PTs and PTTS. Medical Laboratory Observer, September 1991, p. 13.
5. Koepke, J.A., McLaren, C.E., Wijetunga, A.M., Houwen, B.: A method to examine the need for duplicate testing of common coagulation tests. Am J Clin Pathol 102, #2, 242-246, 1994.
6. Draper, N. and Smith, H. Applied Regression Analysis. Second Edition. John Wiley & Sons, New York, 1981.
7. Siegel, S. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill, New York, 1956.
8. Depalma, L., Rush, R.A., and Luban, N.L. The precision of duplicate prothrombin time and partial thromboplastin time assays in neonates. Arch Pathol Lab Med 1992; 116: 657-659.
9. Foucar, K. and Nymeyer, V. To replicate or not to replicate, that was the question. Amer J Clin pathol 84:407, 1991.
10. James, P.L. Duplicate testing for PT/PTT: time for a change? Diagnostics & Clinical Testing. 27 Nov/Dec: 21-23, 1989.
11. Keshgegian, A.A., Mann, J.M., and Cooper, J.H. Duplicate testing for prothrombin time and activated partial thromboplastin time necessary. Arch Pathol Lab Med, 110: 520-522, 1986.
12. Scheer, W.D., Catrou, P.G., Lipscomb, G.E., Nd Boudreau, R.A. A comprehensive evaluation of the performance of duplicate prothrombin time and activated partial thromboplastin time assays. Am J Clin Pathol 85: 456-462, 1986.

Acknowledgments

This research was supported in part by a Cooperative Research and Development Agreement with the Sysmex Corporation, Los Alamitos, CA.

A Small Sample Signal-to-Noise Corrected Consistent Model Selection Criterion

By Allan McQuarrie, NDSU

Abstract

Information theoretic derived model selection has long been popular in the literature. These methods often use maximum likelihood estimates, MLE and other large sample approximations. We develop a model selection criterion based on the distributions of logarithms of the sample sums of squared errors, log(SSE). Model selection depends on the differences for some model selection criterion between two different models. For nested models, the distribution of these differences can be computed. The expected ifference is called the signal. The standard deviation of the difference is called the noise. We develop penalty terms that are stronger than the noise. Small sample signal-to-noise ratios of overfitting and underfitting are derived for a special case regression model. Simulation results for this special case model is also presented.

KEY WORDS: Least squares, MLE

1. Introduction

A central problem in regression is the selection of an appropriate model from a potentially large class of candidate models. The term appropriate is used loosely here. Depending on the author, the definition of appropriate model changes. A common assumption in regression is that the true model is of infinite dimension or that the true model does not belong to the set of candidate models. Under this assumption, the appropriate model is that model which is closest to the true model in some well defined sense. In large samples, a model selection criterion that chooses models with minimum squared error distance (6) is said to be *asymptotically efficient.*

Many researches assume that the true model is of finite dimension and furthermore, that the true model is included in the set of candidate models. Now, the appropriate model is no less than the true model itself. Indeed, the goal of model selection in this case is to correctly identify the true model. A model selection criterion that asymptotically identifies the correct model with probability one is said to be *consistent.* Hannan and Quinn derived one such consistent model selection criterion. We derive a new consistent model selection criterion based on Hannan and Quinn.

Model selection criteria can be treated as random variables since they are functions of the data only. A typical model selection criterion chooses as best model that candidate model where the criterion attains its minimum. When comparing two candidate models, the better model has the smaller value for the criterion. These comparisons can be expressed as a difference. The distribution of these differences under suitable conditions can be studied. We define the signal as the expected difference and the noise as the standard deviation of the difference. The signal-to-noise ratio is the signal divided by the noise. The signal-to-noise ratio allows one to examine first and second moments of model selection criteria in small samples.

Hannan and Quinn (1979) developed their model selection criterion HQ based on properties of the law of the iterated logarithm. They and later authors defined HQ as

$$\mathrm{HQ} = \log(\hat{\sigma}^2) + \frac{2k \log\log(n)}{n} \qquad (1)$$

where n is the sample size, k is the number of variables in the model including the intercept, and $\hat{\sigma}^2$ is the MLE (5) for the residual variance. Originally designed for the autoregressive time series model, HQ is easily applied to regression. Many authors, including Hannan, have found that HQ has disappointing performance in small samples. Indeed, HQ overfits in that HQ tends to choose models that contain variables unrelated to the model. We show that this is due to a weak signal-to-noise ratio due to a weak penalty term in small samples. We propose a signal-to-noise corrected variant, HQL, with a stronger small sample penalty term. HQL is defined as

$$\mathrm{HQL} = \log(\hat{\sigma}^2) + \frac{2k \log\log(n)}{n-k} \qquad (2)$$

2. The regression model

Consider the regression model

$$Y = X\beta + \epsilon \quad (3)$$

and

$$\epsilon \sim N(0, \sigma^2 I_n). \quad (4)$$

Y is an $n \times 1$ vector of responses; X is a known $n \times K$ design matrix of rank K; β is a vector of unknown regression parameters. Consider fitting a model of order k, where rank$(X) = k$. The usual maximum likelihood parameter estimates are

$$\hat{\beta} = (X'X)^{-1}X'Y,$$

$$\hat{Y} = X\hat{\beta},$$

$$\text{SSE}_k = \| Y - \hat{Y} \|^2,$$

$$\hat{\sigma}_k^2 = \frac{\text{SSE}_k}{n}. \quad (5)$$

Suppose there exists a true model. This true model has order $k_* = \text{rank}(X_*)$. We refer to the general model of order $k = \text{rank}(X)$ and overfitting by L variables as the model of order $k+L$, $L > 0$. Performance of model selection in small samples can be measured by counting the number of correct model selection in simulations. We believe that it is also useful to measure how close the selected model is to the true model. We use two measures for this. Suppose there exists a true model $Y = X_*\beta_* + \epsilon$ with $\epsilon \sim N(0, \sigma_*^2 I_n)$. The first is the L_2 or squared error distance. L_2, scaled by the sample size. is defined as

$$L_2 = \frac{1}{n}(mu_* - \mu)'(mu_* - \mu),$$

where μ_* denotes the expected value vector of Y under the true model and μ denotes the expected value vector of Y under the candidate model. In regression models, $\mu_* = X_*\beta_*$, $\mu = \hat{Y}$, and

$$L_2 = \frac{1}{n}(X_*\beta_* - X_k\hat{\beta})'(X_*\beta_* - X_k\hat{\beta}). \quad (6)$$

The second is the Kullback-Leibler information or discrepancy between two models. Using the normality assumption, Kullback-Leibler discrepancy, scaled by $2/n$, is defined as

$$\text{K-L} = \log\left(\frac{\hat{\sigma}_k^2}{\sigma_*^2}\right) + \frac{\sigma_*^2}{\hat{\sigma}_k^2} + \frac{L_2}{\hat{\sigma}_k^2} - 1, \quad (7)$$

with L_2 from (6) and $\hat{\sigma}_k^2$ is the MLE (5).

3. Distributional Results

To evaluate moments of HQ and HQL, we introduce some useful distributional results involving $\log(\text{SSE}_k)$. A key assumption is that the general model of order k and the overfit model of order $k + L$ form nested models. Furthermore, assume that $k \geq k_*$ so that all distributions are central. It can be shown (Gradshteyn, pg. 576, eq 4.352-1) that

$$E\left[\log(\text{SSE}_k)\right] = \log(\sigma^2) + \log(2) + \psi\left(\frac{n-k}{2}\right),$$

where

$$\psi(z) = -C - \sum_{j=0}^{\infty}\left(\frac{1}{j+z} - \frac{1}{j+1}\right)$$

is Euler's psi function and C = .577 215 664 901 is Euler's constant. It follows that $E[\log(\text{SSE}_k)]$ has no closed form. Apply a Taylor expansion, expanding $\log(\text{SSE}_k/\sigma^2)$ about $E(\text{SSE}_k/\sigma^2) = n-k$. We have

$$E\left[\log(\text{SSE}_k)\right] \doteq \log(\sigma^2) + \log(n-k) - \frac{1}{n-k}. \quad (8)$$

The distribution of differences between SSE_k and SSE_{k+L} is more involved. Note that

$$\log(\text{SSE}_{k+L}) - \log(\text{SSE}_k) = \log\left(\frac{\text{SSE}_{k+L}}{\text{SSE}_k}\right),$$

$$\frac{\text{SSE}_{k+L}}{\text{SSE}_k} \sim \text{Beta}(n-k-L, L),$$

and

$$\log\left(\frac{\text{SSE}_{k+L}}{\text{SSE}_k}\right) \sim \text{logbeta}(n-k-L, L).$$

It can also be shown (Gradshteyn, pg. 538, eq. 4.253-1 and pg. 541, eq 4.261-1) that

$$var\left[\log\left(\frac{\text{SSE}_{k+L}}{\text{SSE}_k}\right)\right] = \psi'\left(\frac{n-k-L}{2}\right) - \psi'\left(\frac{n-k}{2}\right)$$

where

$$\psi'(z) = \sum_{j=0}^{\infty} \frac{1}{(j+z)^2}, \ z > 0.$$

No closed form exists and we apply a Taylor expansion. Expanding $\log(\text{SSE}_{k+L}/\text{SSE}_k)$ about $E(\text{SSE}_{k+L}/\text{SSE}_k) = (n-k-L)/(n-k)$, we have

$$var\left[\log\left(\frac{\text{SSE}_{k+L}}{\text{SSE}_k}\right)\right] \doteq \frac{2L}{(n-k-L)(n-k+2)}.$$

Hence, the standard deviation is

$$sd\left[\log\left(\frac{\text{SSE}_{k+L}}{\text{SSE}_k}\right)\right] = sd[\Delta\log(\text{SSE})] \doteq \frac{\sqrt{2L}}{\sqrt{(n-k-L)(n-k+2)}}. \quad (9)$$

Although the Taylor expansions yield approximate results, we drop the $\doteq$ in the following sections.

4. Derivation of HQL

We derive HQL under the more general models k and $k+L$ where $k \geq k_*$, $k < n$ and $0 < L < n-k$ and k_* denotes the true model order. Consider HQ (1). We choose model k over model $k+L$ if $\text{HQ}_{k+L} > \text{HQ}_k$. Let $\Delta\text{HQ} = \text{HQ}_{k+L} - \text{HQ}_k$. Applying (8), the signal is

$$E(\Delta\text{HQ}) = \log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2\log\log(n)L}{n}.$$

From (9), the noise is

$$sd(\Delta\text{HQ}) = sd[\Delta\log(\text{SSE})] = \frac{\sqrt{2L}}{\sqrt{(n-k-L)(n-k+2)}}.$$

The signal-to-noise ratio is

$$\frac{E(\Delta\text{HQ})}{sd(\Delta\text{HQ})} = \frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}}\left[\log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2\log\log(n)L}{n}\right].$$

Examine the signal-to-noise ratio term-by-term. We find that for n, k fixed, the first term,

$$\frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}}\left[\log\left(\frac{n-k-L}{n-k}\right)\right] \to 0$$

as L increases to $n-k$. The second term,

$$\frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}} \times \left[-\frac{L}{(n-k-L)(n-k)} + \frac{2\log\log(n)L}{n}\right] \to -\infty$$

as L increases to $n-k$. The signal-to-noise ratio of HQ increases for small L, then decreases to $-\infty$ as L increases yielding small sample overfitting problems. It is the second term that causes small sample overfitting in HQ.

In HQ, consider substituting the penalty term $2k\log\log(n)/(n-k)$ for $2k\log\log(n)/n$. This yields, HQL (2). We choose model k over model $k+L$ if $\text{HQL}_{k+L} > \text{HQL}_k$. Let $\Delta\text{HQL} = \text{HQL}_{k+L} - \text{HQL}_k$. Applying (8), the signal is

$$E(\Delta\text{HQL}) = \log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2n\log\log(n)L}{(n-k)(n-k-L)}.$$

From (9), the noise is

$$sd(\Delta\text{HQL}) = \frac{\sqrt{2L}}{\sqrt{(n-k-L)(n-k+2)}}.$$

The signal-to-noise ratio of HQL is

$$\frac{E(\Delta\text{HQ})}{sd(\Delta\text{HQ})} = \frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}} \left[\log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2n\log\log(n)L}{(n-k)(n-k-L)}\right].$$

The following theorem proves that the signal-to-noise ratio of HQL increases as L increases and is greater than the signal-to-noise ratio of HQ.

Theorem 1

Consider the regression model (3)-(4). For all n, $k < n$, overfitting $L < n-k$, and $k \geq k_*$ where k_* is the order of the true model, the signal-to-noise ratio of HQL increases as L increases and is greater than the signal-to-noise ratio of HQ.

Proof:

Consider the signal-to-noise ratio of HQL, as L increases.

$$\frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}}\left[\log\left(\frac{n-k-L}{n-k}\right)\right] \to 0$$

and

$$\frac{\sqrt{(n-k-L)(n-k+2)}}{\sqrt{2L}} \times \left[-\frac{L}{(n-k-L)(n-k)} + \frac{2n\log\log(n)L}{(n-k)(n-k-L)}\right] = \frac{\sqrt{n-k+2}(2n\log\log(n)-1)}{n-k}\frac{\sqrt{L}}{\sqrt{2(n-k-L)}}$$

increases as L increases to $n-k$. Hence, the signal-to-noise ratio of HQL increases as L increases.

Since HQ and HQL have the same noise, comparing signal-to-noise ratios is equivalent to comparing signals. Note that for all n, $k < n$, $L < n-k$,

$$\frac{2\log\log(n)L}{n} < \frac{2n\log\log(n)L}{(n-k-L)(n-k)}.$$

Hence,

$$\log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2\log\log(n)L}{n} < \log\left(\frac{n-k-L}{n-k}\right) - \frac{L}{(n-k-L)(n-k)} + \frac{2n\log\log(n)L}{(n-k)(n-k-L)}$$

and signal of HQ < signal of HQL. which completes the proof.

Theorem 2

HQL is asymptotically equivalent to HQ.

Proof:

Consider the difference HQL - HQ,

$$\begin{aligned}\text{HQL} - \text{HQ} &= \log(\hat{\sigma}_k^2) + \frac{2k\log\log(n)}{n-k} - \log(\hat{\sigma}_k^2) - \frac{2k\log\log(n)}{n}\\ &= \frac{2k\log\log(n)}{n-k} - \frac{2k\log\log(n)}{n}\\ &= \frac{2k^2\log\log(n)}{n(n-k)}.\end{aligned}$$

For large n, k fixed, this difference is $o\left(\frac{\log\log(n)}{n^2}\right)$ and

$$\lim_{n\to\infty} o\left(\frac{\log\log(n)}{n^2}\right) = 0.$$

The difference between HQL and HQ $\to 0$ which completes the proof. Hannan and Quinn showed that HQ is consistent. Therefore, HQL is also consistent.

5. Signal-to-noise ratios

Consider the special case for the regression model (3)-(4). $n = 35$, $\sigma^2 = 1$, $k_* = 6$, $X'X = nI$, the intercept $\beta_1 = 0$, and $\beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 1$. We derive small sample signal-to-noise ratios for this special case. All candidate models include the constant. Here, $k = \text{rank}(X) =$ constant $+ k-1$ X variables. Table 1 below shows the signal-to-noise ratios computed for choosing the true model, $k_* = 6$ over the candidate model of order k. These are pairwise and not joint comparisons. Higher signal-to-noise ratios imply smaller probabilities of choosing the incorrect model. The signal-to-noise ratio for choosing the true model over itself is defined to be 0. Also note that $k = 2, 3, 4, 5$ represent underfitting and involve noncentral distributions. L represents the amount of overfitting.

Table 1. Signal-to-noise ratio for model 1.

k	L	HQL	HQ
2		5.892	6.225
3		5.415	5.708
4		4.725	4.957
5		3.597	3.746
6	0	0	0
7	1	1.420	0.703
8	2	2.062	0.957
9	3	2.594	1.126
10	4	3.080	1.246
11	5	3.544	1.332
12	6	3.999	1.390
13	7	4.454	1.426
14	8	4.916	1.442
15	9	5.389	1.441
16	10	5.879	1.424
17	11	6.391	1.391
18	12	6.930	1.344
19	13	7.502	1.282
20	14	8.113	1.208

Table 1 shows the strong signal-to-noise ratio for HQL. Note that the signal-to-noise ratio of HQ increases and then decreases for large $L > 8$. Strong signal-to-noise ratios for underfitting indicate that neither model selection criteria should underfit in this regression model.

6. Simulation Study

The use of the term model, now refers to each of the 1024 possible subsets. Each subset is itself a candidate model. We refer to these candidate model subsets as simply models. The overall special case regression model will be referred to as the regression model.

For the simulation study, six other model selection criteria are included. AICc (Hurvich and Tsai, 1989), AICc= $\log(\hat{\sigma}^2) + (n+k)/(n-k-2)$. AIC (Akaike, 1973), AIC= $\log(\hat{\sigma}^2) + 2k/n$. FPE (Akaike, 1969), FPE= $\hat{\sigma}^2(n+k)/(n-k)$. BIC (Akaike, 1978), BIC= $\log(\hat{\sigma}^2) + k\log(n)/n$. Mallows Cp (Mallows, 1973), Cp= $\text{SSE}/s^2_{max} - n + 2k$. These along with HQ and HQL choose the best model after comparing all subsets including the constant only model. Also included is the stepwise F-test as described in Rawlings (Rawlings, pg 175). We use $\alpha = 0.15$, with $\alpha_{enter} = \alpha_{remove}$, denoted by F15.

L_2 is the observed L_2 (6) distance. The table below displays the models which are closest to the true model in the L_2 sense. K-L is the observed Kullback-Leibler (7) distance. Like L_2, the table below also displays the models which are closest to the true model in the Kullback-Leibler sense.

Consider the special case regression model described above. For purposes of generating the design matrix X, the $X'X = nI$ assumption is replaced by x_{ij} *i.i.d.* $N(0,1)$ $i = 2, \cdots, 11$, and $j = 1, \cdots, n$ with $x_{1,j} = 1$, $j = 1, \cdots, n$. For each of the 1000 replications, a new X matrix and ϵ vector is generated. Due to the large number of subsets, it is impractical to summarize the individual models chosen. Hence, the table summarizes $k = \text{rank}(X)$ of the selected subset. The true model is of order 6. However, $k = 6$ may include models with the correct number of variables but are not the true model. Efficiency is defined as the ratio of the distance for the selected model divided by the minimum distance for all 1024 models.

Table 2 Simulation results for model 1.

counts

k	AICc	AIC	FPE	HQL	HQ	BIC	Cp	L2	KL	F15
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	2	0	0	3	0	3	0	0	1	0
6	564	284	305	619	391	579	411	1000	942	427
7	319	355	352	298	365	295	357	0	27	374
8	96	240	238	73	171	93	167	0	17	151
9	17	95	86	6	61	27	55	0	11	44
10	2	24	17	1	10	3	8	0	2	4
11	0	2	2	0	2	0	2	0	0	0
true	561	284	305	616	391	576	411	1000	926	425

L_2 efficiency summary for selected models

	AICc	AIC	FPE	HQL	HQ	BIC	Cp	L2	KL	F15
ave	.79	.67	.68	.81	.71	.79	.72	1.00	.95	.73
sd	.27	.26	.27	.26	.27	.27	.27	0.00	.18	.27
rank	3	8	7	1	6	2	5			4

K-L efficiency summary for selected models

	AICc	AIC	FPE	HQL	HQ	BIC	Cp	L2	KL	F15
ave	.73	.60	.61	.76	.65	.74	.66	.98	1.00	.67
sd	.31	.29	.29	.30	.30	.31	.31	.08	0.00	.31
rank	3	8	7	1	6	2	5			4

The results indicate that HQL performs quite well in this example. The β parameters are strong and a true model belonging to the set of candidate models exists. HQL correctly identifies the true model over 61% of the time. HQ performs much worse than HQL, identifying the true model only 39% of the time. HQ typically overfits and chooses models with extraneous variables. BIC, another consistent model selection criterion, also performs well. HQL and BIC tend to choose models which are closest to the true model as well. This can be seen in terms of their average efficiencies. AICc is one of the best of the efficient model selection criteria. AICc finishes a close third place. AICc is a small sample Kullback-Leibler corrected variant of AIC. AIC and FPE are derived under asymptotic conditions and both perform poorly in small samples. The F-test and Mallows Cp perform near the middle. Neither performs nearly as well as AICc.

Observed L_2 and K-L efficiencies are included primarily to present the models these observed efficiencies selected and to show the amount of underfitting and overfitting expected. L_2 attains its minimum at the true model in all 1,000 replications. K-L attains its minimum at the true model in 942 of the replications.

7. Conclusion

The performance of HQL is quite good in the above special case regression model. HQL overfits much less than HQ. We feel that the signal-to-noise approach is a useful tool in studying small sample performance of model selection criteria. The signal-to-noise approach offers insight in making improvements in existing model selection criteria with poor small sample performance.

References

Akaike, H. (1969). Fitting autoregressive models for prediction. *The Annals of the Institute of Statistical Mathematics*, 21:243-247.

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principal. In Petrov, B. N. and Csaki, F., editors, *2nd International Symposium on Information Theory*, pages 267-281, Budapest. Akademia Kiado.

Akaike, H. (1978). A Bayesian analysis of the minimum AIC procedure. *The Annals of the Institute of Statistical Mathematics*, A 30: 9-14.

Gradshteyn, I. S. and Ryzhik, I. M. (1965). *Table of Integrals, Series, and Products.* Academic Press, New York.

Hannan, E. J. and Quinn, B. G. (1979). The determination of the order of an autoregression. *Journal of the Royal Statistical Society, B*, 41: 190-195.

Hurvich, C. M. and Tsai, C. L. (1989). Regression and time series model selection in small samples. *Biometrika*, 76: 297-307.

Mallows C. L. (1973). Some comments on Cp. *Technometrics*, 15: 661-675.

Rawlings, J. O. (1988). *Applied Regression Analysis: A Research Tool.* Wadsworth & Brooks/Cole, California.

Shibata, R. (1980). Asymptotic efficient selection of the order of the model for estimating parameters of a linear process. *The Annals of Statistics*, 8: 147-164.

CONSTITUTION of the NORTH DAKOTA ACADEMY of SCIENCE

(Founded 1908, Official State Academy 1958)

ARTICLE I – **Name and Purpose**

1. This association shall be called the NORTH DAKOTA ACADEMY of SCIENCE (NDAS).

2. The purpose of this association shall be to promote and conduct scientific research and to diffuse scientific knowledge.

ARTICLE II – **Membership**

1. Membership in the NDAS shall be composed of persons active or interested in some field of scientific endeavor. Candidates for membership may be proposed by any active member of the NDAS by submitting the candidate's name to the chairman of the Membership Committee for approval. Specific categories of membership shall be defined in the bylaws of the NDAS.

2. Annual dues for the various categories of membership shall be determined by the members present at the Annual Meeting.

ARTICLE III - **Officers**

1. The Officers of the NDAS shall be a President, President-Elect, and the Secretary-Treasurer who shall perform the duties usually pertaining to these offices. The President-Elect shall be chosen by ballot at the Annual Meeting and will hold the office for one year and then assume the office of President for one year. The Secretary-Treasurer shall be appointed for a three-year term by the Executive Committee.

2. The Executive Committee, consisting of the above-named officers, the retiring President, and three members-at-large, shall have charge of the ordinary executive duties. The members-at-large shall be elected for a three-year term on a rotating basis.

ARTICLE IV – **Meetings**

1. There shall be an Annual Meeting each year held at such time and place as the Executive Committee may determine.

2. Special meetings shall be called by the President upon the request of ten percent of the active members. Only matters specified in the call can be transacted at a special meeting.

3. Ten percent of the active members shall constitute a quorum at the Annual Meeting. Special meetings require twenty percent of the active members for a quorum.

ARTICLE V – **Miscellaneous**

1. In the event of dissolution of the NDAS, any remaining assets shall be distributed to organizations organized and operated exclusively for educational and scientific purposes as shall at the time qualify as exempt organizations under Section 501(c) (3) of the Internal Revenue Code of 1954.

2. No substantial part of the activities of the NDAS shall be the carrying on of propaganda, or otherwise attempting to influence legislation, and the Academy shall not participate in or intervene in, any political campaign on behalf of any candidate for public office.

3. No part of any net earnings shall inure to the benefit of, or be distributable to, NDAS members or officers, or other private persons, except that the academy may authorize the payment of reasonable compensation for services rendered.

ARTICLE VI – **Amendments**

1. This Constitution may be amended at any Annual Meeting of the NDAS by a two-thirds vote. Proposed amendments shall be submitted in writing to the Secretary who shall send them to the members at least two weeks before the meeting at which such amendments are to be considered.

2. Bylaws may be adopted or repealed at any regular meeting by a two-thirds vote.

BY - LAWS of the NORTH DAKOTA ACADEMY of SCIENCE

1. The NDAS official guide for parliamentary procedure shall be the "Standard Code of Parliamentary Procedure" by Alice F. Sturgis. (1965 Revision)
2. The annual dues shall be determined by a two-thirds vote at an Annual Meeting. These dues are payable 1 January of each year. (1965 Revision)
3. Members shall be dropped from the active list on 31 December following the nonpayment of dues during the membership year commencing the previous 1 January. A member may return to the active list by paying the current year dues and a membership renewal charge of $5.00. (1975 Revision)
4. Every member in good standing shall receive a copy of the annual Proceedings of the North Dakota Academy of Science. (1965 Revision)
5. Special offices such as Historian may be created by the unanimous vote of the members at the Annual Meeting. (1965 Revision)
6. The Executive Committee shall annually appoint an Academy representative to the National Association of Academies of Science and to Section X (General) of the American Association for the Advancement of Science. (1979 Revision)
7. The Committee structure of the NDAS shall be as follows, the ***President*** appointing the members and chairpersons for all except the Executive Committee:

a. **Executive Committee.**
Membership: Past-President, President, President-Elect, Secretary-Treasurer, three members-at-large. { Three-year terms. }
Duties: The Executive Committee shall be the governing board of the NDAS, responsible only to the membership. It shall arrange for programs, approve committee appointments, be responsible for the fiscal affairs of the Academy, and transact such business as necessary and desirable for function and growth of the NDAS.

b. **Editorial Committee.**
Membership: Three members. { Three-year terms. }
Duties: The Editorial Committee shall develop and recommend the NDAS publication program and policies to the Executive Committee. It will assist the Editor in reviewing manuscripts for the Proceedings.

c. **Education Committee.**
Membership: Seven members, two shall be high school teachers. { Five-year terms. }
Duties: The Education Committee shall work with high school students and teachers in the state, in visitation programs, Science Talent Search programs, and other programs to stimulate an interest in science by the youth of the state. It shall operate the Junior Academy of Science program and administer the AAAS high school research program.

d. **Denison Awards Committee.**
Membership: Six members. { Three-year terms. }
Duties: The Denison Awards Committee shall have as its prime duty the judging of student research and paper competitions, both undergraduate and graduate, and any other similar competitions. The committee shall also maintain the criteria to be used in the judging and selection of papers, such criteria to be circulated to prospective competitors. (1985 Revision)

e. **Necrology Committee.**
Membership: Three members. { Three-year terms. }
Duties: The Necrology Committee shall report to the annual meeting on those departed during the preceding year. Obituaries may be included in the minutes of the annual meeting and/or published in the Proceedings.

f. **Nominating Committee.**
Membership: The five most recent past-presidents.
Duties: The Nominating Committee shall propose a slate of at least two nominees for each of the offices as needed. The committee report shall be submitted to the President prior to the annual meeting as well as reported to the membership at the appropriate time for action.

g. **Resolution Committee.**
Membership: Three members. { Three-year terms. }
Duties: The Committee on Resolutions shall prepare such resolutions of recognition and thanks as appropriate for the annual meeting. Further, the Committee shall receive suggested resolutions for the membership and transmit such resolutions and the Committee recommendation to the membership.

h. **Membership Committee.**
Membership: Unlimited number. { Appointed annually. }
Duties: The Membership Committee shall promote membership in the NDAS. It shall conduct an annual canvass of the Institutions of Higher Education, Government Agencies, and other related organizations for the purpose of providing opportunity for prospective members to join the NDAS. Further, this Committee shall make recommendations to the Executive Committee of potential candidates for emeritus and honorary memberships.

8. The *Nominating Committee* shall be responsible for all nominations to elective office and shall be required to advance at least two names for each open position. Academy members shall have been encouraged to suggest nominees to the committee prior to the Committee submitting its report. A ballot, incorporating brief biographical information, shall be distributed by the Secretary-Treasurer to all members prior to the Annual Meeting. Those ballots may be returned by mail, or in person at the Annual Meeting, until the announced deadlines. The results of the election shall be announced at the Annual Meeting.

9. ***Categories of Membership***:

a. *Active members* -- shall be persons interested or actively participating in some scientific endeavor. Active members may participate in all activities of the NDAS.

b. *Student members* -- shall be graduate or undergraduate College students in some field of science. Student members may participate in all activities of the NDAS, with the exception of holding office.

c. *Sustaining members* -- are persons or organizations interested in the activities of the NDAS. Sustaining members may participate in all activities of the NDAS, with the exception of voting or holding office. Sustaining members may be of three types: Individual, Corporate, or Institutional. (1965 Revision)

This bylaw subsection is implemented by the following action of the Executive Committee (10-25-85):

There shall be two categories of Sustaining Membership, *Patron* members and *Sponsor* members. The annual membership fee shall be $100 for *Patron* members and $50 for *Sponsoring* members. Benefits accruing to Corporate Sustaining Members include:

1. Positive public relations through support of science and technology in North Dakota.
2. Preference in mounting commercial displays at the annual meetings of the NDAS.
3. Early access to research results and early awareness of research programs through first hand association with scientists and engineers.
4. Improved commercial opportunities through association with members, institutions, and other sustaining members.
5. Improved future commercial opportunities through exposure to students contemplating careers in science or technology.

Until action is taken otherwise, the Corporate Sustaining Membership fees shall be placed in the North Dakota Science Research Foundation for the support of scientific research.

d. *Emeritus Membership*. Any member in good standing upon formal retirement is eligible for emeritus membership. Nominations may be forwarded to the Membership Committee by any member, and it shall be the responsibility of the membership committee to review the membership list for possible candidates. The Executive Committee shall approve nominations. Emeritus members shall retain all rights of active members but will be exempt from payment of dues. (1973 Revision)

e. *Honorary Membership*. The Academy may recognize, by awarding honorary membership, any person (nonmember or member) who has in any way made an outstanding contribution to science. It shall be the responsibility of the Membership Committee to be aware of individuals whom it would be fitting for the NDAS to honor in this fashion. Any member may submit nominations along with supporting data to the Membership Committee. Approval of nominations shall be by a two-thirds majority of those attending the annual meeting. (1973 Revision)

10. The President, with the approval of the Executive Committee, shall appoint members to serve on *ad hoc* committees. Reports of *ad hoc* committees shall be presented to the Executive Committee or to the annual meeting. Ad hoc committees serve only during the tenure of the president who appointed them. (1965 Revision)

11. The Executive Committee shall appoint an Editor who shall edit the PROCEEDINGS. The Editor shall be appointed for a three-year term. The salary of the Editor shall be set by the Executive Committee. (1975 Revision)

12. The annual dues shall be $15.00 per year for professional members, with $2.00 designated for the North Dakota Science Research Foundation, and $5.00 per year for student members. (1994 Revision)

13. The Executive Committee is empowered to charge a publication fee of authors of up to $10.00 per page. (1965 Revision)

14. All student research participants shall receive a properly inscribed certificate and be invited to the banquet dinner as the guests of the NDAS. (1965 Revision)

15. All activities of the Academy, including grant applications, are to be handled through the Academy Offices from now on. (1966 Revision)

16. The Executive Committee of the NDAS is instructed to establish a **J Donald Henderson Memorial Fund** and to administer this fund so that the proceeds will be used to promote science in North Dakota. (1967 Revision)

17. The fiscal year of the North Dakota Academy of Science, for the purpose of financial business, shall be 1 January to 31 December. (1973 Revision)

18. The NDAS establishes the North Dakota Academy of Science Achievement Award to be given periodically to a NDAS member in recognition of excellence in one or more of the following:
    a. Nationally recognized scientific research.
    b. Science education.
    c. Service to the NDAS in advancing its goals.

The Nominating Committee will administer the selection process, will develop a separate funding source for a monetary award, and will develop, for Executive Committee approval, the criteria for the award. (1988 Revision)

19. The **North Dakota Science Research Foundation** is established as an operating arm of the NDAS. The purposes of the Foundation are:
    (1) to receive funds from grants, gifts, bequests, and contributions from organizations and individuals, and
    (2) to use the income solely for the making of grants in support of scientific research in the State of North Dakota.

Not less than 50% of the eligible monies received shall be placed in an endowment from which only the accrued interest shall be granted.

The foundation shall be responsible for soliciting the funds for the purposes described. The Foundation funds shall be in the custody of the Secrettary-Treasurer of the NDAS and shall be separately accounted for annually.

The *Foundation Board of Directors* shall be comprised of five memebers of the NDAS, representing different disciplines. Members shall be appointed by the President for staggered five year terms. The chairperson of the Board shall be appointed annually by the President. The Board shall be responsible for developing operating procedures, guidelines for proposals, evaluation criteria, granting policies, monitoring procedures, and reporting requirements, all of which shall be submitted to the Executive Committee for ratification before implementation.

The Foundation shall present a written and oral report to the membership of the NDAS at each annual meeting, and the Secretary-Treasurer shall present an accompanying financial report. (1989 Revision)

By-Laws last revised, May, 1994.

THE NORTH DAKOTA ACADEMY OF SCIENCE

P.O. Box 5567, University Station, Fargo, ND 58105

MINUTES of the Annual Business Meeting 21 April, 1995 North Dakota Heritage Center Bismarck

1. The Annual Business Luncheon of the NDAS began at 12:30 in the North Dakota Heritage Center, State Capital grounds, Bismarck. About 100 were in attendance (30% more than attended the Fargo meeting) including participants, parents and teachers associated with the Junior Academy of Science and the Denison Research paper competitions, members of the Academy and guests (including Carol Two Eagles Walker).

2. By 12:55, thanks to the very efficient functioning of all judges for all divisions of the "student research paper competitions", Secretary-Treasurer Garvey was able to announce the winners and present certificates and awards as follows:

Junior Academy of Science -- Junior Division

The presentations by the three students were of such similar quality that the judges requested that the awards by divided equally as follows:

Jannae Mauch Certificate of participation and a check for $50.00
Joshua D Pankow Certificate of participation and a check for $50.00
Mike Hamling Certificate of participation and a check for $50.00

All three students are from Hankinson.

Junior Academy of Science -- Senior Division

Thirteen student presentations were evaluated leading to the following awards:

Clif Haugen First place Certificate of participation, a check for $100 and an award of $150 available toward tuition if attending a North Dakota Institution of Higher Education.
Patty Schiltz Second place Certificate of participation and a check for $50.00
Douglas Ramsey Third place Certificate of participation and a check for $25.00
Peter Haugen Third place Certificate of participation and a check for $25.00

The names of the four students identified above will be submitted to the Minnesota Academy of Science as presenters to attend the Minnesota Academy Junior Science and Humanities Symposium, 8-10 October, 1995.

Amy Braaten and Ryan Kavlie will be nominated to receive Honorary AAAS membership.

Clif Haugen was selected to receive the $100 savings bond for the best Chemistry related project given by the Red River Valley Section of the American Chemical Society.

In the absence of Glen Statler (or designee) the NDSU Plant Pathology award was not given.

A Rodger Denison Student Research Competition -- Undergraduate

Four student presentations were evaluated leading to the following awards:

Steven Philbrick First place Certificate of participation and a check for $100.00
Michelle Taylor Runner up Certificate of participation and a check for $ 50.00

A Rodger Denison Student Research Competition -- Graduate

Thirteen student presentations were evaluated leading to the following awards:

Emiko Hatcher First place Certificate of participation and a check for $100.
Wen Jiang Runner up Certificate of participation and a check for $ 50.00
Chad Prosser Runner up Certificate of participation and a check for $ 50.00
Carol GustafsonRunner up Certificate of participation and a check for $ 50.00

When (if?) we are more organized, we would hope to also provide each participant with a summary *critique*. The ***INTERIM*** Director of the North Dakota Junior Academy of Science and the Secretary-Treasurer of the North Dakota Academy of Science wishes to express the grateful appreciation of all the members for the sacrifices and conscious efforts of all those who were coerced, conscripted, and impressed into service as judges for this occasion. ***THANK YOU!***

3. The luncheon continued until 1:15. The Participants the meal as pleasing as was the Banquet the previous evening. We wish to express our thanks, with compliments, to Rothenberger Catering, for the excellence of the meals.

ORGANIZED 1908 — STATE ACADEMY 1958

4. About 20 members moved to the Projects room of the North Dakota Heritage Center where Secretary Treasurer Garvey convened the Annual Business Meeting. The conspicuous absence of Carolyn Godfread, President, was noted. The passing of Charles A Hoffman and Warren Whitman was noted by Michael Thompson for the Necrology Committee. 41 students and 57 professionals (with about 20 additional "students of science" from the local area) were attending sessions of the meeting (139 attended the meeting in Fargo last year). 75 attended the Banquet Thursday night (70% more than attended in Fargo). An additional 20-30 arrived for the Lecture presented by John Hoganson (Sea Lilies, Dinosaurs, and Wooly Mammoths: the Fossil Record of Prehistoric Life in North Dakota).

5. Secretary-Treasurer Garvey introduced Eileen STARR of Valley City State University, president of the Academy for the 1995-1996 year. President Starr outlined the plans for our next Annual Meeting in Valley City, 25-26 April, 1996. Using a theme of **Science Research and Regional Economic Development** the local committee proposes to involve Science, Education, and Industry in a multifaceted look at present conditions and potential future developments. President Starr will be contacting "major players" seeking commitments of participation. A more detailed statement will be forthcoming in May.

6. Secretary-Treasurer Garvey next presented the results of the election. Of approximately 350 members of the Academy, 27 ballots were submitted by closing of the ballot box (7.7%). Donna Stockrahm noted that the presentation of the ballot caused it to be easily overlooked. Garvey accepted the criticism, noting that a 15% increase in printing costs for basic white pages (more for color) due to increasing cost of paper has led him to place more lines of a given page and to move away from separate pages for ballots and the like. He will reconsider presentation for next year.

For President Elect Curtiss HUNT, Human Nutrition Research Center, Grand Forks
For Member at Large Allen Kihm, Earth Sciences, Minot State University

The newly elected members of the Executive Committee join with President Starr, Past President Godfread, Secretary-Treasurer Garvey and Members at Large Patricia Kelley and Dan Mott.

7. RESOLUTION presented for action. "Because of the relatively poor attendance at Academy meetings in recent years and because the Academy is an important forum for exchange of ideas and research results and because the majority of research productivity is still centered around UND and NDSU, be it resolved that the Executive Committee reinstitute the practice of scheduling meetings at UND and NDSU, with the third year at one of the other academic institutions." *Ohm Madhok John Reid David Hein*

Discussion ranged over a variety of items associated with the central question of "why has active participation in the Academy declined over the past several years". Acceptance of Academy presentations in support of promotion and tenure decisions, time and schedule conflicts with other "meetings" of both local and national organizations, perceptions, priorities, ... In the end, the request to formally act on the motion was tabled with the understanding that the Executive Committee had received word of the concern and will be taking action. In effect, it was suggested that "each member will be asked to state "why he/she did/does not attend the annual meeting and/or present results of ongoing research at the annual Meetings of the Academy."

8. RESOLUTION presented for action. "Because the Academy is the official Academy of the State of North Dakota, and because the Academy is an important forum for exchange of ideas and research results, and because the Academy offers an important opportunity for students to present research papers, thereby encouraging further research, and because the finances of the Academy have diminished greatly in recent years, be it resolved that the Executive Committee once again make a concerted effort to solicit financial contributions from the institutions of higher learning in North Dakota and appropriate societies (*e g* Sigma Xi, the Red River Valley Section of the American Chemical Society, ..) and other corporations as appropriate. *John Reid, David Hein, Om Madhok*

With very little discussion, the resolution was passed with unanimous acclamation.

9. RESOLUTION presented for action. Whereas the Academy is is participating in a program recognizing the centennial of the creation of the North Dakota Geological Survey, and the centennial of the North Dakota Historical Society, be it resolved that the Secretary-Treasurer in instructed to write a formal letter of appreciation to John Hoganson for his efforts far and above the call of duty making this 87th Annual Meeting of the Academy the success it has been.

10. Om Madhok, Chairman of the North Dakota Science Research Foundation Board of Directors reported the granting of the Second Annual award of $500.00 for the use by Karyn A Alme in support of a project entitled "Genesis and Characterization of Polygonal Features in Western North Dakota". Secretary-Treasurer Garvey was directed to process the necessary acceptance forms and issue the corresponding check.

11. Om Madhok reminded us that the the clock was approaching 2:00 pm and the paper resulting from the First annual award from the Science Research Foundation was about to be presented.

Meeting adjourned.

Your Secretary-Treasurer wishes to personally thank all of those participating in the 87th Annual Meeting. Your generous assistance in a time of need is greatly appreciated. I realize many over sights and omissions were made, but through your kind understanding, the meeting turned into one of our more successful in terms of content and value to those attending. I only hope that this spirit of cooperation will infect the evolution of meetings in the future. Again,

THANK YOU !

Roy Garvey
Secretary-Treasurer

EXECUTIVE COMMITTEE

Curtiss HUNT, President Elect -98
Human Nutrition Research Center, Grand Forks, ND
58202 9034 701.795.8423
cHunt @ badlands.NoDak.edu

Carolyn GODFREAD, Past President -96
216 West Avenue F Bismarck, ND 58501
701.223.2546

Patricia KELLEY, *Member at Large* -96
Department of Geology/Geo Engineering UND
Grand Forks, ND 58202 8358 701.777.2811
Patricia_Kelley @ mail.UND.NoDak.edu

Roy GARVEY, *Secretary-Treasurer* -96
Chemistry, North Dakota State University,
Fargo, ND 58105 5516 701.231.8697
NU025304 @ VM1.NoDak.edu

Eileen STARR, President -97
Division of Sciences, Valley City State University
Valley City, ND 58072 701.845.7522
Starr @ vm1.NoDak.edu

Allen KIHM, Member at Large -98
Division of Science, Minot State Uniersity
Minot, ND 58707 5002 701.845.7452
kihm @ warp6.cs.misu.NoDak.edu

Daniel MOTT, *Member at Large* -97
Department of Natural Science Dickinson State
University, ND 58601 4896 701.227.2111
Daniel_Mott @ DSU1.dsu.NoDak.edu

EDITORIAL COMMITTEE

John HAMMEN *Chairman* -96
University of North Dakota

? ? ? ? -97

Alen KIHM -98
Minot State University

RESOLUTIONS COMMITTEE

David HEIN, *Chairman* -96
University of North Dakota

? ? ? ? -97

? ? ? ? -98

NOMINATING COMMITTEE

Carolyn GODFREAD -00
Bismarck, ND

John BRAUNER -98
Jamestown College

Clark MARKELL **-96**
Minot State University

Glen STATLER, *Chairman* -99
Plant Pathology, NDSU, Fargo

? ? ? ? (Wykoff) -97

NECROLOGY COMMITTEE

Michael THOMPSON -96
Minot State University

? ? ? ? -97

EDUCATION COMMITTEE

State Science Fair
Om Madhok -98

State Science Olympiad
Roy Garvey -00

Junior Academy of Science
Jo Herbel HNRC, co Director -99
Lana Stallard HNRC, co Director -99

Media Representative
? ? ? ? ? -00

Dennis DISRUD -96
Minot State University

Robert BIEK -96
North Dakota Geologic Survey

Harold FISH -97
Watford City

? ? ? ? ? -97

DENISON AWARDS COMMITTEE

Lyle PRUNTY -96
North Dakota State University

Bruce JENSEN -98
Jamestown College

? ? ? ? -97

Daniel MOTT, Chairman -96
Dickinson State University

Eric HUGO -98
Dickinson State University

? ? ? ? -97

NORTH DAKOTA SCIENCE RESEARCH FOUNDATION BOARD of DIRECTORS

David BERRYHILL, *Chairman* -96
North Dakota State University

? ? ? ? ? -98

? ? ? ? -00

Jim WALLA -97
University of North Dakota

Daniel MOTT -99
Dickinson State University

MEMBERSHIP COMMITTEE

Gary CLAMBEY
North Dakota State University

Daniel MOTT
Dickinson State University

Joseph STICKLER
Valley City State University

Dorothy JOHANSEN
Mayville State University

Vernon FEIL
USDA- Bioscience Research Laboratory

Frank KOCH
Bismark State College

James PENLAND, *Chairman*
Human Nutrition Research Center

Michael THOMPSON
Minot State University

David BERRYHILL
North Dakota State University

LOCAL ARRANGEMENTS COMMITTEE -- Valley City

Facilities:	**Alice BEAUCHMAN**	A V:	**Gilbert KUIPERS**
Housing/Parking:	**Val MORITZ**	Banquet:	**Eileen STARR**
Lunch/Refreshm:	**Eileen STARR**	Tours:	**Gilbert KUIPERS**
Keynote Speakers:	**Carolyn BRAUNER**	Social Hours:	**Eileen STARR**
Funding:	? ? ?	Public Relations:	**Val MORITZ**
Registration:	**Marge GARVEY**	Coordinator:	**Eileen STARR**

PAST PRESIDENTS

and Location of the Annual Meeting of the

NORTH DAKOTA ACADEMY of SCIENCE

1909	M A Brannon	Grand Forks
1910	M A Brannon	Fargo
1911	C B Waldron	Grand Forks
1912	L B McMullen	Fargo
1913	Louis VanEs	Grand Forks
1914	A G Leonard	Fargo
1915	W B Bell	Grand Forks
1916	Lura Perrine	Fargo
1917	A H Taylor	Grand Forks
1918	R C Doneghue	Fargo
1919	H E French	Grand Forks
1920	J W Ince	Fargo
1921	L R Waldron	Grand Forks
1922	Daniel Freeman	Fargo
1923	Norma Preifer	Grand Forks
1924	O A Stevens	Fargo
1925	David R Jenkins	Grand Forks
1926	E S Reynolds	Fargo
1927	Karl H Fussler	Grand Forks
1928	H L Walster	Fargo
1929	G A Talbert	Grand Forks
1930	R M Dolve	Fargo
1931	H E Simpson	Grand Forks
1932	A D Wheedon	Fargo
1933	G C Wheeler	Grand Forks
1934	C I Nelson	Fargo
1935	E A Baird	Grand Forks
1936	L R Waldron	Fargo
1937	J L Hundley	Grand Forks
1938	P J Olson	Fargo
1939	E D Coon	Grand Forks
1940	J R Dice	Fargo
1941	F C Foley	Grand Forks
1942	F W Christensen	Fargo
1943	Neal Weber	Grand Forks
1944	E A Helgeson	Fargo
1945	W H Moran	Grand Forks
1946	J A Longwell	Fargo
1947	A M Cooley	Grand Forks
1948	R H Harris	Fargo
1949	R B Witmer	Grand Forks
1950	R E Dunbar	Fargo
1951	A K Saiki	Grand Forks
1952	Glenn Smith	Fargo
1953	Wilson Laird	Grand Forks
1954	C O Clagett	Fargo
1955	G A Abbott	Grand Forks
1956	H B Hart	Jamestown
1957	W E Cornatzer	Grand Forks
1958	W C Whitman	Fargo
1959	Arthur W Koth	Minot
1960	H J Klosterman	Fargo
1961	Vera Facey	Grand Forks
1962	J F Cassel	Fargo
1963	C A Wardner	Grand Forks
1964	Fred H Sands	Fargo
1965	P B Kannowski	Grand Forks
1966	Paul C Sandal	Fargo
1967	F D Holland, Jr	Grand Forks
1968	W E Dinusson	Fargo
1969	Paul D Leiby	Minot
1970	Roland G Severson	Grand Forks
1971	Robert L Burgess	Fargo
1972	John C Thompson	Dickinson
1973	John R Reid	Grand Forks
1974	Richard L Kiesling	Fargo
1975	Arthur W DaFoe	Valley City
1976	Donald R Scoby	Fargo
1977	Om P Madhok	Minot
1978	James A Stewart	Grand Forks
1979	Jerome M Knoblich	Aberdeen
1980	Duane O Erickson	Fargo
1981	Robert G Todd	Dickinson
1982	Eric N Clausen	Bismark
1983	Virgil I Stenberg	Grand Forks
1984	Gary Clambey	Fargo
1985	Michael Thompson	Minot
1986	Elliot Shubert	Grand Forks
1987	William Barker	Fargo
1988	Bonnie Heidel	Bismark
1989	Forrest Nielsen	Grand Forks
1990	David Davis	Fargo
1991	Clark Markell	Minot
1992	John Brauner(elect)	Grand Forks
1993	John Brauner	Jamestown
1994	Glen Statler	Fargo
1995	Carolyn Godfread	Bismarck
1996	Eileen Starr	Valley City

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
ASSETS	31483.43	30902.44	33655.5	34486.88	38027.91	36264.02	32697.24	33535.75	33511.86	33511.86
Operating Accounts										
Checking	2579.2	611.27	1741.74	3381.24	3205.93	1575.30	1930.74	23.89		
Savings / Certificates	7634.09	6625.74	6232.93	2000.00						
Trust Accounts										
Scholarship Principal	15361.13	16505.83	17166.26	19536.06	23953.30	23358.98	19113.39	21160.16	21160.16	21160.16
Research Foundation	5909.01	7159.60	8514.57	9569.58	10868.68	11329.74	11653.11	12351.70	12351.70	12351.70
LIABILITIES	26106.64	26958.71	28165.83	30865.64	37261.98	35388.72	31006.50	33589.86	33511.86	33511.86
Advanced Dues Payments	1585.00	1285.00	585.00	760.00	1540.00	700.00	240.00	78.00		
Restricted Purpose Funds										
Scholarship Principal	15361.13	16505.83	17166.26	19536.06	23953.30	23358.98	19113.39	21160.16	21160.16	21160.16
AAAS Grant	900.00		1900.00	1000.00	900.00					
Research Foundation	5909.01	7159.60	8514.57	9569.58	10868.68	11329.74	11653.11	12351.70	12351.70	12351.70
Cash	2351.50	2008.28								
ACCUMULATED SURPLUS	5376.79	3943.73	5489.67	3621.24	765.93	875.30	1690.74	-54.11	0.00	0.00
CHANGE in SURPLUS		-1433.06	1545.94	-1868.43	-2855.31	109.37	815.44	-1744.85	54.11	0.00
=======================	======	======	======	======	======	======	======	======	======	======
OPERATING CASH FLOW										
CASH on HAND 1 January	10135.49	10292.90	8415.30	8027.02	5381.24	3205.93	1575.30	1930.74	23.89	23.89
RECEIPTS for Year	14258.92	9748.43	11173.58	9021.40	8144.73	6329.45	9227.03	6578.95		
RESOURCES Available	24394.41	20041.33	19588.88	17048.42	13525.97	9535.38	10802.33	8509.69	23.89	23.89
DISBURSEMENTS	14101.51	11626.03	11561.86	11667.18	10320.04	7960.08	8871.59	8485.80		
CASH BALANCE 31 December	10292.90	8415.30	8027.02	5381.24	3205.93	1575.30	1930.74	23.89	23.89	23.89
Increase over Year	157.41	-1877.60	-388.28	-2645.78	-2175.31	-1630.63	355.44	-1906.85		
=======================	======	======	======	======	======	======	======	======	======	======

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
DUES	3617.00	2992.00	2680.00	2755.00	3320.00	1806.00	2560.02	2350.00	0.00	0.00
Reinstatements	67.00	50.00	90.00	20.00	90.00	50.00	37.00			
Current year	1965.00	1657.00	2005.00	1975.00	1690.00	980.00	2156.00	1673.00		
Future years	1585.00	1285.00	585.00	760.00	1540.00	700.00	240.00	78.00		
Sponsor/Patron						76.00	127.02	599.00		
INSTITUTIONS	1950.00	2200.00	2200.00	1200.00	200.00	200.00	390.08	1200.00	0.00	0.00
								1200.00		
U N D	1000.00	1000.00	1000.00							
N D S U	750.00	1000.00	1000.00	1000.00			90.08			
Minot State	200.00	200.00	200.00	200.00	200.00	200.00	300.00			
Jamestown College										
INDUSTRY	0.00	0.00	0.00	200.00	0.00	0.00	0.00	0.00		
Basin Electric				100.00						
Red River Sugarbeet Grow				100.00						
ANNUAL MEETING	6398.20	3460.00	3613.04	2286.00	2252.00	2998.00	3820.00	1631.00	0.00	0.00
Registration Fees	1800.00	2810.00	2191.00	1377.00	1729.00	1970.00	3400.00	1005.00		
Banquet Ticket Sales	1965.00			809.00	423.00	350.00	370.00	526.00		
Assocn ND Geographers		50.00			50.00	50.00	50.00			
Sigma Xi – UND	50.00	50.00	50.00	50.00	50.00			50.00		
Sigma Xi – Minot		50.00		50.00				50.00		
Sigma Xi – NDSU		100.00	150.00							
SD Academy	233.20									
ND Geol Society	50.00	100.00	100.00							
Subsidy	2000.00					28.00				
RRV Amer Chem Sco	300.00	300.00	350.00							
NDSU Engineering			772.04							
Jamestown College						600.00				

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
AWARDS PROGRAMS	1647.50	481.78	2375.20	2355.65	2226.40	1473.51	2756.35	1285.45	0.00	0.00
AAAS Sec Schl Research	900.00		1900.00	1000.00	900.00		900.00			
Scholarship Dividends	747.50	481.78	475.20	612.15	372.40	708.45	818.45	829.45		
ND Research Foundation				743.50	954.00	765.06	1037.90	456.00		
PUBLICATION SALES	167.00	123.00	102.00	52.00	106.00	154.00	179.50	112.50		
INTEREST on SAVINGS	479.22	491.65	203.34	172.75	40.33					
	======	======	======	======	======	======	======	======	======	======
TOTAL INCOME	14258.92	9748.43	11173.58	9021.40	8144.73	6631.51	9705.95	6578.95	0.00	0.00
MEMBERSHIP										
Emeritus	60	58	59	54	56	57	58	52		
Students	43	53	61	104	41	47	47	41		
Professional	283	290	290	312	210	211	202	161		
Deliquent				86	115	163	151	140		
Dropped		58			86	55	78	88		
Other						13	18	19		
	======	======	======	======	======	======	======	======	======	======
TOTALS	386	459	410	556	508	546	554	501		

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
ANNUAL MEETING	6708.68	3564.03	3928.22	3007.59	2915.66	2563.36	1833.57	2504.71	0.00	0.00
Speakers Expenses	2651.40	973.83	1122.07	514.00	918.16	513.80				
Meals/Refreshments	2734.36	1856.30	1929.39	1903.95	1656.30	838.50	1455.32	2504.71		
Printing				589.64	320.20	448.30				
General Expenses	1322.92	733.90	876.76		21.00	762.76	378.25			
AWARDS PROGRAMS	1360.00	1725.00	1100.00	1975.00	1750.00	1600.00	2075.00	1300.00	1350.00	1350.00
AAAS Sec Schl Research	710.00	900.00	700.00	1200.00	900.00	800.00	800.00			
ND Science Olympiad				100.00						
ND Science/Engineer Fair	25.00			50.00	50.00	50.00	50.00	50.00	50.00	50.00
Denison Awards	500.00	450.00	400.00	300.00	400.00	300.00	450.00	400.00	400.00	400.00
ND Jr Academy Awards				325.00	400.00	450.00	375.00	350.00	400.00	400.00
Dunbar/Henderson Award	125.00	175.00								
Abbott Scholarship		200.00								
Research Fdn Grant							400.00	500.00	500.00	500.00
PUBLICATIONS	2353.84	2836.65	3883.37	2883.28	2704.00	2406.00	3369.00	2507.00	3000.00	3000.00
Proceedings	2103.84	2586.65	3133.37	2633.28	2704.00	2406.00	3369.00	2507.00	3000.00	3000.00
Editor Fees	250.00	250.00	750.00							
Dakota Science Teacher				250.00						
PROGRAM OPERATIONS	475.60	55.80	471.55	132.76	255.19	41.75	0.00	0.00	700.00	700.00
Junior Academy			350.00	132.76					200.00	200.00
Exec Committee	475.60	55.80	121.55		255.19	41.75			500.00	500.00

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
OFFICE EXPENSES	2171.92	2376.25	1199.49	1857.55	1648.59	1103.97	1487.85	673.61	1208.00	1208.00
Postage	762.72	403.16	550.56	1194.95	924.08	702.54	589.68	268.74	400.00	400.00
Post Office Box Rental	39.00	39.00	39.00	39.00	49.00	49.00	49.00	58.00	58.00	58.00
Duplicating	218.68	215.08	208.42	324.95	392.26	300.56	631.00	283.21	400.00	400.00
Supplies	414.02	349.01	259.01	228.65	98.25	51.87	87.40	63.66	100.00	100.00
Clerical Assistance	137.50	170.00	92.50	70.00	185.00		125.00		250.00	250.00
Sec Treas Fee	600.00	1200.00	50.00							
Phone							5.77	2.96	20.00	20.00
MISCELLANEOUS	1031.47	1068.30	979.23	1811.00	1046.60	245.00	106.17	1499.00	96.00	96.00
Fidelity Bond	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00	26.00
AAAS Delegate Expenses	960.57	1000.00	911.73	1000.00						
NAAS Dues	44.90	42.30	41.50	41.50	66.60	60.00	60.00	70.00	70.00	70.00
Funds Transfers				743.50	954.00	159.00				
Other							20.17	1403.00		
	======	======	======	======	======	======	======	======	======	======
TOTAL DISBURSEMENTS	14101.51	11626.03	11561.86	11667.18	10320.04	7960.08	8871.59	8485.80	6364.00	6364.00

SCIENCE RESEARCH FOUNDATION

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
CASH INCOME										
Donations from Members	279.00	296.50	270.00	261.50	303.00	159.00	159.00	212.00		
Allocations from Dues	678.00	544.00	438.00	482.00	651.00	304.00	400.00	244.00		
Intrest Accrued	250.57	310.09	396.97	311.51	345.10	302.06	478.90	425.08		
Sponsors / Patrons	300.00	100.00	250.00							
Other Sources										
TOTAL	1507.57	1250.59	1354.97	1055.01	1299.10	765.06	1037.90	881.08	0.00	0.00
CASH EXPENSE										
Grants							400.00	500.00		
Awards										
Interest Compounding	250.57	310.09	396.97	311.51	345.10	302.06	302.39	425.08	0.00	0.00
Other Disbursements	1257.00	940.50	958.00	743.50	954.00	159.00	0.00	18.00		
TOTAL	1507.57	1250.59	1354.97	1055.01	1299.10	461.06	702.39	943.08	0.00	0.00
in checking NET CHANGE	0.00	0.00	0.00	0.00	0.00	304.00	335.51	-62.00	0.00	0.00
ASSETS										
Pass Book Savings 31 Dec	4401.44	5909.01	7159.60	8514.57	9569.58	11329.74	1653.11	2060.19	2060.19	2060.19
Investment 1							T-Note			
Book Value							10000.00	10000.00	10000.00	10000.00
Investment Value TOTAL	5909.01	5909.01	8514.57	9569.58	10868.68	11329.74	11653.11	12060.19	12060.19	12060.19
CHANGE	1507.57	1507.57	1250.59	1354.97	1055.01	461.06	323.37	407.08	0.00	0.00

SCHOLARSHIP FUND

Fiscal Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
CASH INCOME										
S D G E Dividends	257.50	267.50	270.00	205.00	70.00	407.00	415.25	426.25		
I E S Industries	490.00	214.28	205.20	216.00	302.40	407.20	403.20	403.20		
CD Interest					13.59					
AAAS Sec Schl Research	900.00		1900.00	1000.00	900.00		900.00			
TOTAL	1647.50	481.78	2375.20	1421.00	1285.99	814.20	1718.45	829.45	0	0
CASH EXPENSE										
Denison Awards	500.00	450.00	400.00	300.00	400.00	300.00	450.00	400.00	400.00	400.00
Junior Academy Awards				325.00	400.00	500.00	375.00	350.00	400.00	400.00
AAAS Mini Grant	710.00	900.00	700.00	1200.00	900.00	800.00	800.00			
ND Science/Engineer Fair	25.00			50.00	50.00	50.00	50.00	50.00	50.00	50.00
Dunbar / Henderson Award	125.00	175.00								
Abbott Scholarship		200.00								
TOTAL	1360.00	1725.00	1100.00	1875.00	1750.00	1650.00	1675.00	800.00	850.00	850.00
NET CHANGE	287.50	-1243.22	1275.20	-454.00	-464.01	-835.80	43.45	29.45	-850.00	-850.00
ASSETS										
SDGE Shares (1983) 250	277.06	289.48	302.00	315.18	657.40	694.36	725.68	758.86	758.86	758.86
Price 18.50	38.25	45.13	43.63	45.00	29.50	25.00	19.63	23.75	23.75	21.44
Value 4625.00	10597.55	13064.23	13176.26	14183.10	19393.30	17359.00	14241.39	18022.88	18022.88	16271.59
IES Industries (1990)			120.00	192.00	192.00	192.00	192.00	192.00	192.00	192.00
Price 120 @ 31.63			33.25	27.88	23.75	31.25	25.38	27.00	27.00	25.00
Value 3795.60			3990.00	5352.96	4560.00	6000.00	4872.00	5184.00	5184.00	4800.00
TOTAL Investment Value	10597.55	13064.23	17166.26	19536.06	23953.30	23359.00	19113.39	23206.88	23206.88	21071.59
CHANGE		2466.69	4102.03	2369.80	4417.24	-594.30	-4245.61	4093.49	-0.00	-2135.29

Remembrance

Dr Benjamin DeBoer, Emeritus professor of Physiology and Pharmacology at the University of North Dakota School of Medicine and a member of the Academy since 1952, died 16 May, 1995, at the age of 83. Dr DeBoer received his Ph.D. in Pharmacology from the University of Missouri, Columbia, and taught Pharmacology at the University of Missouri, as well as at Saint Louis University prior to coming to the University of North Dakota School of Medicine. In 1951 he was appointed as the first Professor of Pharmacology in the then combined Department of Physiology and Pharmacology. From 1951 through 1976, Dr DeBoer served as a mainstay in pharmacology and coordinated the pharmacology teaching and research efforts within the combined department. Dr DeBoer assumed many duties in the combined Department of Physiology and Pharmacology including service as acting Chairman from 1951 - 1964. Dr DeBoer was instrumental in recruiting faculty, which included Dr Ted Auyong. Dr DeBoer retired in 1976 and was appointed Professor Emeritus of Physiology and Pharmacology. He continued to reside in Grand Forks, but remained active in teaching and professional activities. He spend one year teaching medical pharmacology at a School of Medicine in Nigeria and taught physiology and pharmacology at several colleges. Dr DeBoer was an outstanding educator and Gentleman who made substantial contributions to the University of North Dakota School of Medicine.

Dr Richard E Frank, a member of the Academy since 1949, died 1 March, 1995. The Academy was very dear to his heart. He attended meetings when he could, and sometimes made contributions.

Harald N Bliss, a member of the Academy since the early fifties.

George W Starcher, a member of the Academy since 1954.

Academy NEWS and VIEWS

It is our hope that in Volume 51 of the PROCEEDINGS these pages will include printed reports from the chairs of the standing Committees:

Executive Committee

Editorial Committee

Resolutions Committee

Nominating Committee

Education Committee

Necrology Committee

Denison Awards Committee

Membership Committee

Local Arrangements Committee

North Dakota Science Research Foundation

detailing the accomplishments/frustrations of the year past. Not only will this serve to inform the membership of past actions and future plans, but will also serve to more formally archive the dealings of the Academy.

EMERITUS

ALESSI, Joseph	1210 Eleventh Street South	FARGO	ND	58103	701 293-1405
ANDERSON, Edwin M	1151 Twelveth Avenue West	DICKINSON	ND	58601	
AUYONG, Theodore	3614 Eleventh Avenue North	GRAND FORKS	ND	58201	701 772-3166
BARNEY, William G	1525 Cottonwood	GRAND FORKS	ND	58201	
BELINSKEY, Carol R	900 Fourth Avenue N W	MINOT	ND	58703	
BOLIN, F M	1505 Sixth Street South	FARGO	ND	58103	701 235-9528
BROPHY, John A	702 South Drive	FARGO	ND	58103	701 235-2772
BROWN, Ralph C	Box 89	STONEHAM	ME	0 4331	
CALLENBACH, John A	North Dakota State University	HULTZ HALL	ND	58105	701 231-7582
CARLSON, Kenneth T	515 East Thirteenth Street	CASPER	WY	82601	
CARMICHAEL, Virgil W	1013 North Anderson Street	BISMARCK	ND	58501	701 223-7986
CARTER, Jack F	1345 Eleventh Street North	FARGO	ND	58102	701 232-0482
CASSEL, J Frank	83 West Boulder Street	COLORADO SPRINGS	CO	80903	
CORNATZER, William E	2033 North Washington Street	BISMARCK	ND	58501	
DAFOE, Arthur W	551 Third Street North East	VALLEY CITY	ND	58072	701 845-2439
DINGA, Gustav P	Concordia College	MOORHEAD	MN	56560	
EDGERLY, Charles	1317 Eighth Avenue South	FARGO	ND	58103	701 235-5105
FISK, Allen L	1122 Avenue B West	BISMARCK	ND	58501	701 223-7447
FOSSUM, Guilford	1828 Cottonwood Street	GRAND FORKS	ND	58201	701 775-7842
HOEPPNER, Jerome J	2518 Nineth Avenue North	GRAND FORKS	ND	58203	
HOLLAND, F D Jr	University of North Dakota	GRAND FORKS	ND	58202	701 777-2531
HOLLAND, Jean H	4686 Belmont Road	GRAND FORKS	ND	58201	701 775-0995
JACOBS, Francis A	1525 Robertson Court	GRAND FORKS	ND	58201	701 772-2447
KANNOWSKI, Paul B	1800 Lewis Boulevard	GRAND FORKS	ND	58203	701 772-4184
KIESLING, Richard	Post Office Box 204	FARGO	ND	58107	
KLOSTERMAN, Harold J	1437 12 Street North	FARGO	ND	58102	701 232-1141
KOLSTOE, Ralph H	2200 South 29th Street # 51S	GRAND FORKS	ND	58201	701 772-3972
KRESS, Warren D	North Dakota State University	STEVENS HALL	ND	58105	701 231-7145
LAIRD, Wilson M	449 Florian Drive	KERRVILLE	TX	78028	210 257-4833
LOW, Frank N	2511 Saint Charles Avenue	NEW ORLEANS	LA	70130	
MARWIN, Richard M	1519 Chestnut Street	GRAND FORKS	ND	58201	701 775-9728
MELDRUM, Alan	512 Columbia Road North	GRAND FORKS	ND	58203	701 772-1166
MINETTE, Ray	209 Fourth Street South West	RUGBY	ND	58368	701 776-6484
MITCHELL, Earl N	220 Glenhill Lane	CHAPEL HILL	NC	27514	
McMAHON, Kenneth J	North Dakota State University	VANES HALL	ND	58105	701 231-7668
NELSON, C N	North Dakota State University	BOTTINEAU	ND	58318	
OWEN, John B	1118 Reeves Drive	GRAND FORKS	ND	58201	701 775-8089
PFISTER, Philip C	North Dakota State University	DOLVE HALL	ND	58105	701 232-5407
ROGLER, George A	1701 Monte Drive	MANDAN	ND	58554	
RUDESILL, James T	1318 Twelveth Street North	FARGO	ND	58102	701 235-4629
SCHMIDT, Claude H	1827 North Third Street	FARGO	ND	58102	701 293-0365
SCOBY, Donald R	North Dakota State University	STEVENS HALL	ND	58105	701 235-3389
SEVERSON, Roland	2682 Catalina Drive	GRAND JUNCTION	CO	81506	
SLEEPER, Bayard P	Post Office Box 2236	PAULSBO	WA	98370	
SMITH, Glenn S	3140 North Tenth Street	FARGO	ND	58102	701 235-6785
SNOOK, Theodore	343 Sheridan Road	RACINE	WI	53403	
SOUBY, Armand M	103 Nichols	SAN MARCOS	TX	78666	
STEWART, James A	Pembroke K8A 1X2	ONTARIO	CANADA		
SUGIHARA, James M	1001 Southwood Drive	FARGO	ND	58103	701 235-8266
SUMMERS, Lawrence	1019 Porter Avenue # 121	BISMARCK	ND	58501	
WALSH, Robert G	Rural Route 6 Box 124 CC Acres	MINOT	ND	58701	
WEISSER, Wilber O	55 Parkview Circle	GRAND FORKS	ND	58201	701 772-4013

STUDENT

ADOLF, Stacy L	Moorhead State University	MOORHEAD	MN	56563	218 236-3347
AESCHAMP, Cameron T	614 Eighth Street N W	MINOT	ND	58703	
ALME, Karyn A	Univeristy of North Dakota	GRAND FORKS	ND	58202	701 777-2821
ALTENBURG, Karl R	709 Nineth Avenue North	FARGO	ND	58102	
ALVAREZ, Enrique	P O Box 324	BISMARCK	ND	58502	
ANDERSON, Shaun	714 Eleventh Avenue North West	MINOT	ND	58701	701 838-6864
ANDREWS, Vicky	University of North Dakota	LEONARD HALL	ND	58202	701 777-2821
BOHUN, Trina P	1029 A Tenth Street NW	MINOT	ND	58701	
CHAMBERS, Michael A	North Dakota State University	THOMPSON HALL	ND	58105	
DAVIDSON, Michelle K	Moorhead State University	MOORHEAD	MN	56563	
DIK, Mickie L	Moorhead State University	MOORHEAD	MN	56563	
ELLINGSON, Jonathan	University of North Dakota	GRAND FORKS	ND	58202	701 777-2821
ENDERS, Todd	P O Box 449	MINOT	ND	58702	
FEIST, Susan A	P O Box 251	MINOT	ND	58702	701 839-7225
FRETLAND, Adrian	University of North Dakota	GRAND FORKS	ND	58202	
GERADS, Jacquie R	Moorhead State University	MOORHEAD	MN	56563	
GRISSO, Cara	UND School of Medicine	GRAND FORKS	ND	58202	701 777-3651
GUSTAFSON, Carol Dawn	UND School of Medicine	GRAND FORKS	ND	58202	701 777-2760
HATCHER, Emiko	UND School of Medicine	GRAND FORKS	ND	58202	701 777-2298
HEGRE, Kyle D	1101 Thirty Second Avenue SW #31	MINOT	ND	58701	
HUBBARD, Trent D	211 Walnut Street Apt 2	GRAND FORKS	ND	58201	701 772-5389
HUGHES, Jean M	1106 Valley View Drive	MINOT	ND	58703	701 838-4810
JEGIER, Jolin A	North Dakota State University	LADD HALL	ND	58105	
KRUMENAKER, Joshua	University of North Dakota	GRAND FORKS	ND	58202	701 777-2289
LADENDORF, B Peter	1121 Third Street NE	MINOT	ND	58703	701 838-0906
LARSON, Jeffrey P	1211 North Redwood Road	SALT LAKE CITY	UT	84116	801 595-0958
LEFF, Matthew	University of North Dakota	GRAND FORKS	ND	58202	701 777-2287
LEWIS, Quincie A	121 University Avenue W	MINOT	ND	58703	
MOEN, R J	UND School of Medicine	GRAND FORKS	ND	58202	
MUESSIG, Karen D	1204 Skyview Drive	BELLEVUE	NE	68005	402 291-2687
MCMILLAN, Justin J	616 Park Street #P	MINOT	ND	58701	
NEWTON, Kenneth R	P O Box 55	BELFIELD	ND	58622	701 575-4418
NGUYEN, Hugh V	UND School of Medicine	GRAND FORKS	ND	58202	
PHILLIPS, Karen A	North Dakota State University	STEVENS HALL	ND	58105	
QUICK, Amy J	Moorhead State University	MOORHEAD	MN	56563	
SCHMITZ, Lowell E	Moorhead State University	MOORHEAD	MN	59563	
SHIRLEY, Geraldine	1315 Eighth Street N W #7	MINOT	ND	58703	701 838-0781
SIMONSEN, Christine M	801 North Sewell	MILES CITY	MT	59301	
SMITH, Terry	University of North Dakota	GRAND FORKS	ND	58202	
SPOONER, Nolan B	708.5 Second Avenue N E	MINOT	ND	58703	
STEGEMAN, Jamie L	Moorhead State University	MOORHEAD	MN	56563	
SWENSON, Erick C	216 Twenty Second Street N W	MINOT	ND	58703	
TAYLOR, Shayne D	320 Third Avenue North	GLASGOW	MT	59230	
TSURU, Asuka	1001 North 18th Street #10	FARGO	ND	58102	
UELAND, Jeffrey	303 South Third Street Apt 2	GRAND FORKS	ND	58203	
URLACHER, Kenneth	Route 2 Box 25	NEW ENGLAND	ND	58647	701 579-4414
WALSH, Nancy J	3415 Twentieth Ave So #310	GRAND FORKS	ND	58201	701 662-4629
WATTERS, Bryan K	Moorhead State University	MOORHEAD	MN	56563	
WILLIAMS, Thomas J	University of North Dakota	GRAND FORKS	ND	58202	
ZEARLEY, Janice	1755 C 34th Street S W	FARGO	ND	58103	701 239-4301
ZHANG, Mingyu	UND School of Medicine	GRAND FORKS	ND	58202	

ANDERSON, Ordean S	Rural Route 1 Box 269	NEW PRAGUE	MN	56071	612 364-8744
ANDERSON, Major Dave	P O Box 5511	BISMARCK	ND	58506	701 224-5287
BARKER, William T	North Dakota State University	HULTZ HALL	ND	58105	701 231-7222
BARKOSKY, Richard R	1209 Soo Street	MINOT	ND	58701	
BARNHART, Michael P	2704 Tenth Avenue North West	MANDAN	ND	58554	701 663-4980
BEHM, Marla	516 North Nineteenth Street	BISMARCK	ND	58501	701 258-7451
BERKEY, Gordon B	Minot State University	MINOT	ND	58707	
BERRYHILL, David L	North Dakota State University	VANES HALL	ND	58105	701 231-7694
BICKEL, David	State Capitol Building	BISMARCK	ND	58501	701 328-2249
BIEK, Robert F	600 East Boulevard Avenue	BISMARCK	ND	58505	701 224-4109
BLAKE, Michael J	UND School of Medicine	GRAND FORKS	ND	58202	701 777-4293
BLUEMLE, John P	600 East Boulevard Avenue	BISMARCK	ND	58505	701 258-4981
BOLAND, E Wayne	North Dakota State University	VANES HALL	ND	58105	701 231-7522
BRAUNER, John F	Jamestown College	JAMESTOWN	ND	58405	
BRAUNER, Carolyn R	Valley City State University	VALLEYCITY	ND	58072	701 795-1924
BREKKE, David W	University of North Dakota	GRAND FORKS	ND	58202	701 777-5154
BUCKLEY, Arthur R	UND School of Medicine	GRAND FORKS	ND	58202	701 777-4294
BURKE, Margaret G	RR 3 Box 19A	MANDAN	ND	58554	701 663-4302
CAMPBELL, Earle H	P O Box 1921	BISMARCK	ND	58502	701 255-3658
CAMPBELL, Johnathan M	408 North Second Street #7	BISMARCK	ND	58501	
CLAMBEY, Gary K	North Dakota State University	STEVENS HALL	ND	58105	701 231-8404
CLAUSEN, Eric N	Minot State University	MINOT	ND	58707	
COLLIER, Jeff	Bismarck State College	BISMARCK	ND	58501	
CONNELL, Marvin D	2606 Fifth Avenue North	GRAND FORKS	ND	58203	701 772-7658
CRACKEL, Robert L	Minot State University	MINOT	ND	58707	
CUNNINGHAM, Richard	4101 West Heart Road	BISMARCK	ND	58504	701 258-6937
DAHLEN, Gwen M	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8498
DAVIS, David G	Bioscience Research Laboratory	FARGO	ND	58105	701 239-1247
DISRUD, Dennis T	413 Hillcrest Drive	MINOT	ND	58701	701 839-3784
DOGGER, James R	P O Box 208	GORE	VA	22637	
DRAPER, Martin A	North Dakota State University	WALSTER HALL	ND	58105	701 231-7854
DRYER, Pamela J	1501 North 12th Street Box 2432	BISMARCK	ND	58502	701 223-1844
DURICK, Mary Ann	Bismarck State College	BISMARCK	ND	58501	
EARNHARDT, Todd S	Rural Route 1 Box 165	FOXHOLM	ND	58738	701 857-3085
EIDE, John D	Northern Crop Science Laboratory	FARGO	ND	58105	701 239-1354
ELHARDT, Dale G	801 25th Street North West	MINOT	ND	58701	701 839-7449
ELSTAD, Yvette	Bismarck State College	BISMARCK	ND	58501	701 224-5586
ERICKSON, J Mark	St Lawrence University	CANTON	NY	13617	315 379-5190
EULISS, Ned H	Northern Prairie Wildlife Resear	JAMESTOWN	ND	58401	
FAFLAK, Richard E	1307 Thirteen 1/2 Street North	MOORHEAD	MN	56560	218 233-6183
FARNUM, Bruce W	Bldg 41-2 Box 33131	SAINT PAUL	MN	55133	612 458-2268
FEIL, Vernon J	Biosciences Research Laboratory	FARGO	ND	58105	701 239-1236
FILLIPI, Gordon M	1005 South Twentieth Street	GRAND FORKS	ND	58201	701 772-4593
FIVIZZANI, Albert J	University of North Dakota	GRAND FORKS	ND	58202	701 777-4671
FORSMAN, Nels	University of North Dakota	GRAND FORKS	ND	58202	701 777-4349
FUNKE, Berdell R	North Dakota State University	VANES HALL	ND	58105	701 231-7846
GARVEY, Roy	North Dakota State University	DUNBAR HALL	ND	58105	701 231-8697
GERLA, Philip J	University of North Dakota	GRAND FORKS	ND	58202	701 777-2811
GERLACH, Tim	University of North Dakota	GRAND FORKS	ND	58202	701 777-5144
GILLIES, George T	4310 Beaver Creek Road	EARLYSVILLE	VA	22936	804 924-3781
GODFREAD, Carolyn	216 West Avenue F	BISMARCK	ND	58501	701 223-2546
GOETTLER, Hans J	North Dakota State University	DOLVE HALL	ND	58105	701 231-8836
GROENEWOLD, Gerald H	University of North Dakota	GRAND FORKS	ND	58202	701 777-5000
HALVORSON, Gary A	Box 459	MANDAN	ND	58554	701 667-3002
HANSON, Michael	Box 74	COOPERSTOWN	ND	58425	701 797-2531
HARTMAN, Joseph H	University of North Dakota	GRAND FORKS	ND	58202	701 777-2551

HASSETT, David J	Energy/Environment Research Cent	GRAND FORK	ND	58202	701 777-5192
HASTINGS, Michael	Dickinson State University	DICKINSON	ND	58601	
HEIDEL, Bonnie	1575 Sixth Avenue	HELENA	MT	59620	406 444-3019
HEILMANN, Larry J	Biosciences Research Laboratory	FARGO	ND	58105	
HEIN, David W	UND School of Medicine	GRAND FORKS	ND	58202	701 777-4293
HEMMASI, Mohammad	University of North Dakota	GRAND FORKS	ND	58202	701 777-4587
HILL, Lynn M	1057 Fourth Avenue West	DICKINSON	ND	58601	
HOFF, Donald L	402 East First Street	VELVA	ND	58790	
HOGANSON, John W	600 East Boulevard	BISMARCK	ND	58505	701 222-4939
HUGO, Eric R	Dickinson State University	DICKINSON	ND	58601	
HULLA, Janis	UND School of Medicine	GRAND FORKS	ND	58202	701 777-6222
HUNT, Curtiss D	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8423
HUNT, Janet R	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8328
JACOBSON, Arlen L	Apartment 206	BISMARCK	ND	58504	701 258-1312
JOHANSEN, Dorothy	Mayville State University	MAYVILLE	ND	58257	701 786-2301
JOHNSON, Douglas H	8711 37th Street South East	JAMESTOWN	ND	58401	
JOHNSON, Phyllis E	800 Buchanan Street	ALBANY	CA	94701	
JOHNSON, W Thomas	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8411
JORDE, Dennis G	U S Fish and WildLife Service	LAUREL	MD	20708	
JUNG, Robert F	2800 Seventh Street	MINOT	ND	58701	
JENSEN, Bruce R	Jamestown College	JAMESTOWN	ND	58405	701 252-34672473
KANG, Y James	University of North Dakota	GRAND FORKS	ND	58202	701 777-4293
KANTRUD, Harold A	Route 7 Box 52	JAMESTOWN	ND	58401	701 252-5639
KARNER, Frank R	University of North Dakota	GRAND FORKS	ND	58202	701 777-2811
KATHREIN, Melanie J	Dickinson High School	DICKINSON	ND	58602	701 579-4631
KEEHR, Kay A	2420 Second Avenue North	GRAND FORKS	ND	58202	
KELLEY, Patricia H	University of North Dakota	GRAND FORKS	ND	58202	701 777-2380
KEYS, Ross D	1836 Billings Drive	BISMARCK	ND	58504	701 255-4211
KIHM, Allen J	Minot State University	MINOT	ND	58707	
KILLINGBECK, James E	North Dakota Department Healt	BISMARCK	ND	58504	701 328-5188
KNULL, Harvey	University of North Dakota	GRAND FORKS	ND	58202	701 777-2786
KOCH, Frank	Bismarck State College	BISMARCK	ND	58501	
KRAFT, Donald J	Bemidji State University	BEMIDJI	MN	56601	218 755-2795
KRUGER, Robert M	Mayville State University	MAYVILLE	ND	58257	701 786-4804
KRUMM, Mark P	Minot State University	MINOT	ND	58707	
KRUPINSKY, Joseph M	Agriculture Research Service	MANDAN	ND	58554	
KUIPERS, Gilbert	Valley City State University	VALLEY CITY	ND	58072	
LAMBETH, David O	University of North Dakota	GRAND FORKS	ND	58202	701 777-3937
LARSON, Omer R	University of North Dakota	GRAND FORKS	ND	58202	701 777-4674
LARSON, Diane L	Northern Prairie Wildlife Resear	JAMESTOWN	ND	58401	701 252-5363
LINCOLN, Terry	P O Box 711	BISMARCK	ND	58502	
LINDLEY, James A	North Dakota State University	AG ENGR	ND	58105	701 231-7273
LINZ, George M	North Dakota State University	STEVENS HALL	ND	58105	701 231-7054
LORENZ, Russell J	1924 North Grandview Lane	BISMARCK	ND	58501	701 223-3421
LOWE, Stephen L	Minot State University	MINOT	ND	58707	
LUDLOW, Douglas K	518 Princeton	GRAND FORKS	ND	58203	
LUNDAY, AudreyAnne	2513 West Central Avenue	MINOT	ND	58701	701 838-2311
LUTHER, Mark	600 East Boulevard	BISMARCK	ND	58505	701 224-4109
LYKKEN, Glenn I	University of North Dakota	GRAND FORKS	ND	58202	701 777-3519
MADSEN, Linda R	621 Fourteenth Street S E	MINOT	ND	58701	701 838-8342
MALMEDAL, Greg A	605 Park Street # 13	MINOT	ND	58701	
MANSKE, Llewellyn L	470 State Avenue	DICKINSON	ND	58601	
MARKELL, Clark	Minot State University	MINOT	ND	58707	701 857-3069
MARTIN, DeWayne C	2104 Seventh Avenue North West	MINOT	ND	58701	701 852-4726
MARTSOLF, John T	UND School of Medicine	GRAND FORKS	ND	58202	701 777-4242
MASON, Harry	Post Office Box 1116	JAMESTOWN	ND	58402	701 252-1247

McCOY-BROWN, Carol	3035 Kincaid Road	BILLINGS	MT	59101	406 657-6361
MEARTZ, Paul D	Mayville State University	MAYVILLE	ND	58257	
MICHELSEN, Kim G	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8357
MIESS, Robert	Mayville State University	MAYVILLE	ND	58257	
MILLER, James E	1925 Halifax Street	LIBERTYVILLE	IL	60048	
MOTT, Daniel J	Dickinson State University	DICKINSON	ND	58601	701 227-2111
MUNSKI, Douglas	University of North Dakota	GRAND FORKS	ND	58202	701 777-4591
MUNSKI, Laura	University of North Dakota	GRAND FORKS	ND	58202	701 772-8207
MacCARTHY, Ronald F	University of North Dakota	GRAND FORKS	ND	58202	701 777-4424
McCARTHY, Greg	North Dakota State University	LADD HALL	ND	58105	701 231-7193
McCOLLOR, Donald P	University of North Dakota	GRAND FORKS	ND	58202	701 777-5121
McCORMACK, David	Minot State University	MINOT	ND	58707	701 857-3281
NELSON, Robert M	North Dakota State University	E E E	ND	58105	701 231-7619
NIELSEN, Forrest H	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8455
OCONNELL, James W	535 Eighth Avenue South West	VALLEYCITY	ND	58072	
OAKLAND, Laura	Pioneer Trails Regional Museum	BOWMAN	ND	58623	701 523-3625
ORR, Paul H	Potato Research Laboratory	EAST GRAND FORKS	MN	56721	218 773-0162
OWENS, Thomas C	University of North Dakota	GRAND FORKS	ND	58202	701 777-4244
PANSEGRAU, Paul D	P O Box 1017	BEULAH	ND	58523	
PEARSON, Dean	Box 589	BOWMAN	ND	58623	
PENLAND, James G	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8471
PERKINS, Dexter	University of North Dakota	GRAND FORKS	ND	58202	701 777-2811
PFLUGHOEFT-HASSET, Debra F	University of North Dakota	GRAND FORKS	ND	58202	701 777-5261
POELLOT, Rhonda Lee	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8406
RAO, Marepalli B	North Dakota State University	WALDRON HAL	ND	58105	701 231-8178
RAWAT, Banmali	University of Nevada Reno	RENO	NV	89557	702 746-1438
RAWSON, Jenny	North Dakota State University	E E E	ND	58105	701 231-7402
RAY, Paul D	University of North Dakota	GRAND FORKS	ND	58202	701 777-3937
REID, John R	University of North Dakota	GRAND FORKS	ND	58202	701 777-2811
RIES, Ronald E	908 Second Avenue North West	MANDAN	ND	58554	701 663-7335
RIGLEY, Louis	515 North Washington Street	BISMARCK	ND	58501	701 255-6575
ROGERS, David A	North Dakota State University	E E E	ND	58105	701 231-7216
ROYER, Ron	Box 88	BURLINGTON	ND	58722	701 838-7648
SAINIEIDUKAT, Bernhardt	North Dakota State University	STEVENS HALL	ND	58105	701 231-8785
SCHAEFER, Nancy O	HCR 3 Box 33	BOWMAN	ND	58623	701 523-5302
SCHEIBE, Paul O	3 Still Creek Road	WOODSIDE	CA	94062	
SCHMID, Thomas	109 Durango Drive	BURLINGTON	ND	58722	701 838-6032
SCHWERT, Donald P	North Dakota State University	STEVENS HALL	ND	58105	701 231-7496
SEABLOOM, Robert W	University of North Dakota	GRAND FORKS	ND	58202	701 777-4676
SEDIVEC, Kevin	North Dakota State University	HULTZ HALL	ND	58105	701 231-7647
SHAFFER, Terry L	2205 Fourth Street North East	JAMESTOWN	ND	58401	701 251-2399
SHULER, Terrence R	2974 Columbine Court	GRAND FORKS	ND	58201	701 772-7919
SIDERS, William A	1105 South Twenty Second Street	GRAND FORKS	ND	58201	701 746-8921
SIMS, Roger L	5050 Fifth Avenue North	GRAND FORKS	ND	58203	701 775-8007
SMITH, Donald A	North Dakota State University	EEEH	ND	58105	701 231-7401
SOVADA, Marsha	8711 37th Street S E	JAMESTOWN	ND	58401	
SPANIER, Jon G	UND School of Medicine	GRAND FORKS	ND	58202	701 777-2750
STARR, Eileen M	Valley City State University	VALLEY CITY	ND	58072	701 845-7522
STATLER Glen D	North Dakota State University	WALSTER HALL	ND	58105	701 231-7058
STEFFAN, Carl R	Jamestown College	JAMESTOWN	ND	58405	701 252-34672485
STICKLER, Joseph C	Valley City State University	VALLEY CITY	ND	58072	701 845-1848
STINNETT, Henry O	UND School of Medicine	GRAND FORKS	ND	58202	701 777-3955
STOAKS, Ralph	5888 Our Way	CITRUS HEIGHTS	CA	95610	916 965-4045
STOCKRAHM, Donna M Bruns	Moorhead State University	MOORHEAD	MN	56563	218 236-2576
SUKALSKI, Katherine A	University of North Dakota	GRAND FORKS	ND	58202	701 777-4049
SWANSON, Judith	1809 Parkside Drive	MINOT	ND	58701	701 852-2260

SWANSON , Richard J	Rural Route 1 Box 102A	RICHVILLE	MN	56576	
THOMPSON, Michael B	2208 Crescent Drive	MINOT	ND	58703	701 839-6305
TODD, Robert G	221 Seventh Avenue West	DICKINSON	ND	58601	701 225-5056
TOMANEK, Debra	North Dakota State University	STEVENS HALL	ND	58105	701 231-7336
ULMER, Michael G	202 East Divide	BISMARCK	ND	58501	701 258-6454
UTHUS, Eric O	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8382
UTTER, Rodney A	North Dakota State University	WALSTER HALL	ND	58105	701 231-7561
VANALSTINE, James B	University of Minnesota	MORRIS	MN	56267	612 589-2535
VANDERPOOL, Richard A	Human Nutrition Research Center	GRAND FORKS	ND	58202	701 795-8416
WALLA, James A	North Dakota State University	WALSTER HALL	ND	58105	701 231-7069
WANEK, Wallace J	16901 Irvine Avenue North West	BEMIDJI	MN	56601	218 243-2245
WOZNIAK, Chris A	Northern Crop Science Laboratory	FARGO	ND	58105	701 239-1358

A space to add the names of new friends and colleagues.

RUSTAN, Timothy D	18, 22
SATRAN, Shelly L	10*
SCHMITZ, Lowell E	38, 39
SCHWALM, Mizuho	23
SHABB, John B	51
SHAFFER, Terry L	41
SIDERS, W A	49*
SLEEPER, M E	55
SPANN, James W	150
SPEAKER, Karen K	57
STEGEMAN, Jamie L	39*
STOCKRAHM, Donna M	38, 39
TAYLOR, Debra L	108, 110*
THOMPSON, Peter	158*
TOMANEK, Debra	42*
VIEUX, Baxter E	119*
VYAS. Nimish B	150*
WAGNER, Rick J	46
WANG, Xiaowei	14*
WARD, Kevin E	8
WATTERS, Bryan K	39
WEGHORST, Chistopher M	18
WIJETUNGA, Ariyaratna M	169*
WILKIE, Timothy R	7*
WOODWARD, Robert O	95, 132
WRUBLESKI, Dale	115*
YIN, Xianhua	28*
ZHANG, Mingyu	21*