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The Proceedings of the North Dakota Academy of Science (NDAS) was first published in 1948 with Volume I reporting the business and scientific papers presented for the 40th annual meeting, May 2 -3, 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 prior to the annual 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 8 1/2 x 11 inch format. It is produced from camera-ready copy submitted by the authors and issued in a single part to be distributed initially at the annual meeting. For the current Volume, all submissions were on computer disk; the entire Proceedings was then assembled by using desktop publishing software. This approach allowed the Editor control over all formatting and many of the papers were reformatted, giving the Proceedings a more consistent look. Also, incorporating all of the submissions on computer allowed production of an electronic copy of the Proceedings for the first time.

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 results and conclusions, and permit data presentation. The communication conveys much more to the reader than did the 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 were given the opportunity to contribute an expanded or full length article consisting of a multiple page contribution thus providing a presentation of much greater depth and scope than possible in a singe page communication.

The communications of this volume of the Proceedings are presented in three sections. The first section contains presentations from the symposium offered at the 89th annual meeting. These papers are organized in the same sequence as presented in the respective symposium. The second section contains the collegiate communication presented in the A. Roger Denison Student Research Paper Competition. The third section of this volume contains the communications presented in the professional sections of the annual meeting. Readers may locate communications by looking within the major sections of these Proceedings (see table of contents) or by referring to the author index.

This issue of the Proceedings also contains the Constitution and Bylaws of the Academy, a list of officers and commmittee members, a list of all Academy members as of April 1998, a copy of approved minutes from the 1997 annual meeting, a copy of unapproved minutes from the 1998 annual meeting, a listing of past presidents of the Academy, and a copy of the 1995, 1996 and 1997 financial statements.

Eric O. Uthus

SYMPOSIUM – WHEAT SCAB

FUSARIUM HEAD BLIGHT ON WHEAT AND BARLEY, ITS EFFECT AND CONTROL

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ECONOMIC IMPACT OF _FUSARIUM_ HEAD BLIGHT ON PRODUCERS AND PEOPLE OF NORTH DAKOTA

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HEALTH EFFECTS AND TOXICITY OF _FUSARIUM_ HEAD BLIGHT

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FUSARIUM HEAD BLIGHT ON WHEAT AND BARLEY, ITS EFFECT AND CONTROL

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ABSTRACT

Fusarium head blight (FHB) or scab has been the most devastating disease of wheat (*Triticum aestivum* L.), durum wheat (*T. Turgidum* L.), and barley (*Hordeum vulgare* L.) in the Upper Midwestern U.S. FHB occurs on wheat and barley from spike emergence through kernel development. Moist conditions and warm temperatures during spike emergence and kernel development favor disease development. Symptoms are typified by dead glumes and spikelets, and often a salmon pink fungal growth is evident. Infected kernels are shrunken with grey brown, chalky, discolored endosperm. Yield, test weight, and kernel vitreousness are all reduced by FHB. The presence of mycotoxins, typically deoxynivalenol, may occur in infected kernels. Reduction in quality from FHB has resulted in market discounts to growers. The epidemic of FHB from 1993-97 can be attributed to two major factors: i) above average rainfall during June and July, and ii) increased minimum and no-till practices. The above average rainfall occurred during a period when the crops were susceptible. The change in tillage practices resulted in more crop residue on the soil surface, increased fungal growth and subsequently higher levels of inoculum. Control of FHB in wheat, durum wheat, and barley is best accomplished by growing the most tolerant cultivars available, using crop rotations to break the disease cycle, and fungicide applications when needed. Control of FHB is essential to ensure a safe supply of quality grain.

Fusarium head blight (FHB), also commonly called scab, has been the most devastating disease of wheat (*Triticum aestivum* L.), durum (*T. Turgidum* L.), and barley (*Hordeum vulgare* L.) in the Upper Midwest. FHB can completely ruin a crop that within a few weeks of harvest is otherwise healthy. Frequent and heavy rain, high humidity and heavy dew during spike emergence and early grain fill in small grains favors development of FHB. Damage from FHB includes: reduced yield, shrunken and discolored kernels, reduced test weight, contamination with mycotoxins and reduced seed quality (1).

Epidemics of FHB are usually associated with warm, wet weather during grain development. Initial infections appear as small water soaked brownish spots on individual florets of the spike (2). Water soaking and discolorationthen spread from the site of infection. A salmon pink fungal growth may be seen along the edge of the glumes or at the base of the spikelet. Infected grains shrink and become grey/brown with a chalky discolored endosperm and are sometimes referred to as tombstones. Premature death and bleaching of spikelets, or the whole spike, is common (3). Following prolonged periods of warm moist weather, spikelets on infected heads can appear speckled from the development of black perithecia.

FHB infected wheat often results in lowered market grade. Market grade is determined by the presence of damaged kernels, foreign material, test weight and percent hard and vitreous kernels (U.S. Grain Marketing Standards). FHB infected kernels are considered damaged, contribute to lowered test weight, and reduce the percent of hard and vitreous kernels of wheat and durum wheat. This is especially true in durum wheat where much of the market quality is based on kernel morphological characteristics, particularly kernel vitreousness.

FHB damaged kernels present problems with processing for food and consequently marketability. Mycotoxins produced by the organism that causes FHB are a major concern to grain processors. When consumed in large enough quantities by non-ruminates, including swine and humans, mycotoxins cause health problems such as vomiting (1, 4). Mycotoxins, primarily deoxynivalenol (DON), in malt have been associated with gushing in beer (5). To maintain quality, much of the malting and brewing industry has a maximum DON level of 0.5 ppm. North Dakota is the largest producer of hard red spring wheat, durum wheat, and barley in the U.S. (6). These crops play a major role in the economy and overall economic well being of the state. The reduction in quality not only affects the producer that is growing the crop but country elevators who purchase the crop, the millers and other customers who have come to rely on North Dakota as a source of number one dark northern spring wheat, number one hard amber durum, and six-rowed malting barley. Continued dissatisfaction with the crops in domestic and international markets will result in loss of market share and lower value for the crop even in years when FHB is not a problem.

The organism that causes FHB on wheat and barley is a fungi in the *Fusarium* genus, principally *F.graminearum* Schwabe. The same organism also causes seedling blight and root rot in small grains and stalk rot and ear rot in corn. The fungus exists as a saprophyte on crop residue of wheat, barley, and corn. The sexual state (*Gibberela zeae* Schwein) typically develops on infected residue producing perithecia. Ascospores released from the perithecia become wind borne and infect developing spikes during warm moist weather. Infection is commonly the result of first becoming established saprophytically on extruded anthers and then growing into the developing kernel. Living tissue can also be directly infected by ascospores. Symptoms typically develop within three days of infection under moist conditions. Secondary infections result from subsequently produced conidia (2).

FHB outbreaks can vary greatly from year to year because the right combination of temperature, moisture, and source of inoculum are required. Outbreaks of FHB have been associated with corn residue that decomposes more slowly than residue from small grains and provides a more sustained source of inoculum (7). Chaff, light kernels and other infected debris of wheat and barley are all returned to the soil surface during harvest and are a major overwintering site of the fungus.

CAUSES OF THE RECENT EPIDEMIC

FHB is certainly not a new disease to North Dakota or the U.S. In the 1880's, reports of FHB becoming a problem on wheat in Ohio were reported (7). In fact, FHB was regarded as common throughout the cereal growing regions of the U.S. (7). In 1982, FHB caused an estimated 4% reduction in total U.S. wheat production, or a total of 100 million bushels (8).

In Eastern North Dakota, *F. graminearum* has probably been present since wheat was grown in the region and certainly isolated pockets of the disease have occurred. The extent of the recent outbreaks of FHB may baffle some, but an examination of recent history provides some very convincing clues to the recent and continuing FHB outbreaks.

In 1993 the Upper Midwest received unusually high rainfall during late June and early July, it was also the first year that FHB was wide spread problem in the Red River Valley. The heavy rainfall occurred during developmental stages of the wheat and barley crop when they were most susceptible to FHB. The outbreak can't be blamed wholly on the high rainfall because this had occurred in previous years, with some FHB, but not the wide spread problem. In the late 1980's, particularly 1988, the region experienced severe drought problems. Rainfall during the critical months of June and July was at historic low levels and wheat, durum wheat, and barley yields were historically low (Fig. 1). Growers were looking for a way to conserve moisture and increase productivity. While actual numbers are difficult to document, minimum tillage and no-till practices were adopted by many growers in the region. U.S. farm programs also encouraged increased minimum-tillage practices. As a whole, the past ten years have seen a move towards minimum tillage practices in the U.S. (9).

The result of minimum tillage and no-till practices was that more crop residue remained on the soil surface. Much of the small grain acreage in North Dakota is grown in a monoculture type system where wheat follows wheat or barley in rotation. These factors combined to provide an optimum environment for fungal growth and inoculum production.

Long-term weather patterns in North Dakota show that June is the highest rainfall month with just over 3.5". During the years 1993 through 1997, rainfall during June was much higher than long-term averages, and nearly double long-term averages during July of this period (Fig. 2). Heading in wheat and barley occurs from late June through mid-July. Heading is also the time during which the crops are most susceptible to infection by *F. graminearum*. The combination of high levels of inoculum and high rainfall during critical developmental stages of the crops have contributed to the severe FHB epidemic of the past five years.

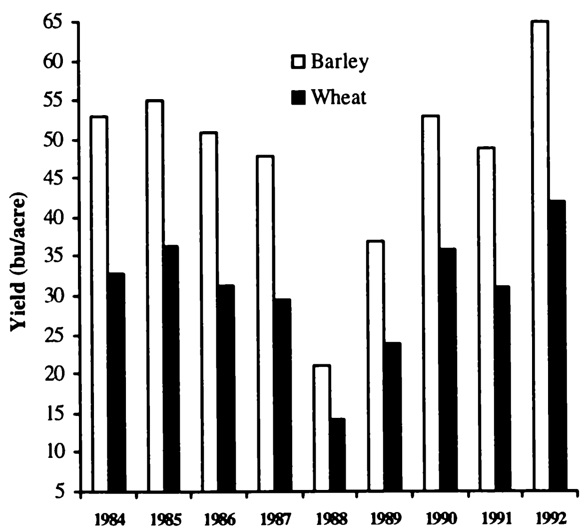

Figure 1. Average grain yield of wheat and barley in North Dakota, 1984–1992 (6).

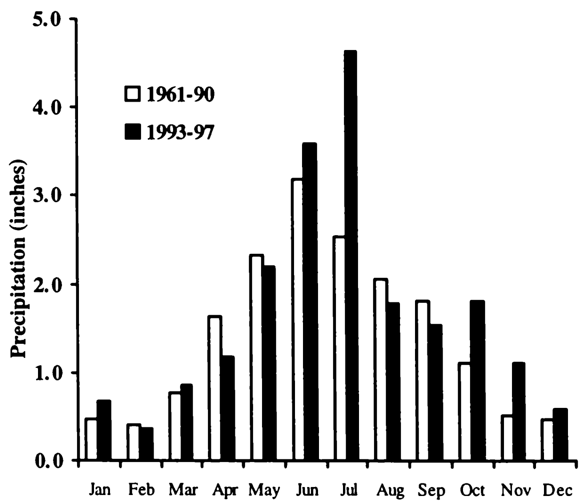

Figure 2. Long term and recent precipitation patterns by month in North Dakota (6).

CONTROL OF FHB

Forecasting disease development is difficult, making control a challenge. FHB is no different, there are no simple or easy control methods. Control of FHB is best achieved by using a combination of the most resistant cultivars, favorable cultural practices, and fungicides when needed.

Resistance

No cultivars of wheat, durum, or barley with a high level of resistance to FHB are available. However, there are differences among cultivars for each of these three crops in their ability to withstand FHB.

Of the hard red spring wheat cultivars grown in North Dakota, response to FHB ranges from very susceptible to moderate. Of the 46 cultivars listed by the NDSU Extension Service, only two have the moderate designation (10). However, final yield performance of some cultivars under heavy infestations of FHB is better than would be expected based on disease severity.

Levels of resistance in durum cultivars are low, with the exception of one cultivar, Belzer. It has a rating of moderately resistant (10). The remaining cultivars range from very susceptible to moderately susceptible. Belzer, the cultivar with moderate resistance, generally is not a top yielding cultivar and will typically have a lower test weight than the other cultivars in a non-FHB environment.

There are two basic types of barley cultivars, six-rowed and two-rowed. Two-rowed cultivars have a higher level of tolerance to FHB than do the six-rowed cultivars. The Upper Midwest has been a historic producer of six-rowed barley for the malting and brewing industry and there is little interest by industry to see this change. Further complicating the issue is the fact that there are few six-rowed cultivars with a malting designation for producers to choose from, none of which have resistance to FHB.

Ultimately cultivars with acceptable quality and a high level of resistance to FHB will be available to growers. In the interim, growers must choose between cultivars with a minimum level of tolerance and give up yield potential or other quality factors that may limit the marketability of the crop. The impact of reduced quality can easily be seen when looking at wheat. Lower quality of the crop due to FHB and the planting of cultivars with some tolerance but poorer overall quality has contributed to complaints from major purchasers of hard red spring wheat from the Upper Midwest (11).

The process of developing a new cultivar is slow. Numerous quality and agronomic factors must be evaluated to find an acceptable genotype. Intense efforts to develop resistant cultivars of wheat, durum, and barley are actively being pursued at the North Dakota Agriculture Experiment Station and surrounding institutions. The release of cultivars with high levels of resistance are anticipated.

Cultural Practices

In the absence of highly resistant cultivars, crop rotation is probably the single best way to reduce the potential for FHB in small grains. Rotation is a way to alter local environmental conditions. Rotating a small grain with a crop that is not a host to FHB can effectively break the disease cycle of the FHB causing organism. In the absence of host crop residue, the FHB causing organism will not be produced to infect a crop the following year. A good rotation will also break the disease cycle of numerous diseases that affect small grains in addition to FHB (Table 1).

Environmental constraints and market availability limit crop options for utilization in a rotation in North Dakota. Environmental limitations include length of growing season and available moisture. Keeping limitations in mind, a rotation should be designed to: reduce the risk of disease, insect, and weed pests; enhance resource management; allow flexibility in crop choices; and result in increased productivity. Table 2 provides a list of crops adapted to North Dakota and a chronological description of how they should be grown in a rotation.

A good rotation allows flexibility in crop choices while maintaining the integrity of the rotation by breaking pest cycles. Crop rotations are only as good as growercommitment to them. An inappropriate crop year substitution will destroy any rotational advantage of the previous year(s). A rotation mutually beneficial to all the crops involved requires a long-term commitment.

Since *Fusarium* spp survives on crop residue, removal of the crop residue would be expected to reduce inoculum levels and disease potential. Several studies have demonstrated that mouldboard ploughing or burning the crop reduces the incidence of FHB on wheat (7). Both burning and deep ploughing reduce soil organic matter and lead to poorer soil structure; however, in high residue situations where high levels of disease inoculum would be expected the benefit of removing residue probably outweighs drawbacks.

Fungicide Applications

Successful and inconsistent results from the use of fungicides to control FHB are summarized by Parry *et al.* (7). The limited success of fungicides often can be attributed, in

Table 1. Disease of small grains commonly controlled with rotations.

Disease	Crop(s) Affected
Scab	wheat[†], barley
Common root rot	wheat, barley, grasses
Bacterial blights	wheat, barley grasses
Tan spot	wheat
Net blotch	barley
Septoria (different species)	wheat, barley
Seedling blight	wheat, barley, oat

[†] Includes hard red spring and durum wheat.

Table 2. Crops adapted for production in North Dakota and some surrounding regions. Rotational benefits are maximized when crops from a common group do not follow each other in a rotation. A crop can be substituted for another of the same crop group in a rotation without destroying rotational benefits. The best rotational benefits are achieved when crops from groups 1 and 2 precede group 3. Crops from group 4 should never precede group 3. Including warm and cool season crops in a rotation will spread out planting and harvest work loads (12).

	Crop Group			
Crop Type	**1**	**2**	**3**	**4**
Cool Season Crop	Field Pea, Lentil, Canola, Mustard, Crambe	Potato, Sugarbeet, Flax	Wheat, Barley, Durum, Oat†, Winter Wheat, Rye	
Warm Season Crop	Dry bean: pinto, navy, black..; Soybean, Sunflower, Safflower	Buckwheat, Flax		Corn, Sudangrass, Millet
Perennial		Alfalfa		

† Scab is generally not a problem on oat.

part, to lack of disease forecasting and application technique. Fungicides must be applied as a protectant, not as a cure. Changes in weather forecasts and limited knowledge on inoculum levels make predicting disease development difficult. Fungicide applications made soon after spike emergence have been the most consistent at reducing FHB on small grains.

FHB development is restricted to the spike of the small grain plant and is the plant part that must be protected. Historically, herbicides are applied to the foliage of plant pests and fungicide applications are made to protect foliage of the developing crop; consequently spray equipment is designed for foliar applications. Research by Gregoire (13) indicates that little of the fungicide applied with traditional sprayers protects developing barley and wheat spike from FHB. Gregoire also found that performance of the same fungicide application could be enhanced by angling flat fan nozzles directing spray towards the spike. To be effective, fungicide applications to control FHB must be done differently than other pesticide applications made by growers.

SUMMARY

FHB impacts many individuals and groups. Researchers are faced with the task of developing resistant cultivars and identifying the best control measures that include cultural practices, fungicides, and new technologies. Growers have the undaunting task of managing farm income while adopting new farming practices and technologies that often requires large capitol investments. Finally the urban population of the region and indeed the world needs the assurance of a wholesome and plentiful supply of grain.

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ECONOMIC IMPACT OF FUSARIUM HEAD BLIGHT ON PRODUCERS AND PEOPLE OF NORTH DAKOTA

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Wheat producers in several states have experienced significant yield losses due to Fusarium Head Blight (FHB), or scab, in recent years. Losses have been especially severe in the spring wheat region, but soft red winter (SRW) producers have also experienced major outbreaks. A study was conducted to measure the economic losses suffered by wheat producers in nine states and three wheat classes during 1991-97. The study was done by D. Demcey Johnson, George K. Flaskerud, Richard D. Taylor and Vidyashankara Satyanarayana. Results of the study are presented in Agricultural Economics Report No. 396.

During the 1990s, wheat producers in FHB-affected regions have suffered cumulative losses of $1.3 billion, according to our analysis. This represents the estimated change in crop value after accounting for reduced yields, higher abandoned acres, and price impacts on futures and basis. The economic losses have been most severe in the spring-wheat growing regions, particularly North Dakota and Minnesota. These two states account for 67.9 percent of the estimated total losses.

One of the main difficulties in measuring economic losses due to FHB is estimating the price effects. While supply reductions tend to increase the futures price, the effects on average basis (difference between local cash price and futures) are less certain. Shortages of milling-quality wheat can induce large price premiums, which favor producers who have high quality wheat to sell. However, many producers in scab-affected regions face quality discounts due to damaged kernels, low test weight, or vomitoxin. The average basis in a region depends on the quality of wheat sold by all producers and the premiums and discounts applied by local elevators.

To measure the impact of scab on basis, we used deviations from olympic-average basis values in years preceding the scab outbreak. Results indicate that the effects on basis were primarily negative in the SRW regions (except in 1996), more than offsetting gains in futures prices. In spring wheat regions, the impacts on basis varied by CRD and year. However, large positive basis effects were estimated in 1993, the year of largest production shortfalls. Combined with the impact on MGE spring wheat futures, this helped to offset much of the economic loss due to scab in that year.

The positive price effect for spring wheat that we estimated for 1993 draws attention to what may be termed an 'aggregation problem.' Our analysis used CRD-level production data and CRD or state-level price data to derive the economic losses suffered by producers. Data at this level of aggregation do not convey the severity of losses for individual producers whose yields and price were lower than average. Moreover, in some CRDs where producers benefitted (on average) from higher prices, scab-related production losses were fairly small or localized. Our estimates of economic loss are affected, unavoidably, by the inclusion of positive price effects for all wheat sold in a CRD–even wheat sold by producers who suffered no yield losses.

This problem notwithstanding, it is clear that many CRDs have suffered major economic losses as a result of FHB. These losses are bound to have broader repercussions at state and regional levels, as producers' losses are felt throughout the economy. Based on results from a state-level input-output analysis for North Dakota (Dean Bangsund and Larry Leistritz, personal communication), the 'multiplier effect' of lost crop value is substantial: for each dollar of lost crop value, state-level economic activity declines by $3.68, after accounting for sectoral linkages and spending patterns within the state economy. If the same multiplier held for other states considered in this study, the cumulative economic impact of FHB during 1991-97 would be $4.8 billion.

There is other, more tangible evidence of economic distress in scab-affected regions. Net farm income for 1997 in the north central region of North Dakota was the lowest since 1989, down 34 percent on average from 1996, according to North Dakota Farm Business Management (FBM) records (North Dakota Farm Business Management Record Program). Net farm income averaged $22,528 during 1997, far short of the $35,000 that FBM records indicate is the typical amount spent per farm for family living (including taxes) in the region. The 20 percent least-profitable farms averaged a negative $16,620 net farm income.

Income losses have resulted in a reduction in farm numbers. About 2,000 farms were lost in North Dakota during 1992-1996, versus 500 during the previous four years, according to North Dakota Agricultural Statistics. This trend may be accelerating during 1998. Auction sale listings (for Mid-March through May) were up 55 percent over a year ago in the March 16 issue of *AGWEEK*, an agricultural publication serving the northern Red River Valley.

Loan activity by the Farm Service Agency (FSA) in northwest Minnesota has doubled since 1997. FSA loans are made to farms that do not qualify for regular bank operating loans. This region, one of the hardest hit by FHB, represented 48 percent of FSA loan activity for Minnesota as of mid-March.

Revenue shortfalls are occurring at a time of rising production costs. Operating costs between 1991 and 1996 increased by 60 percent, according to FBM records for North Dakota. Meanwhile, government assistance is declining. Disaster payments are no longer available to the extent that they were during the early years of the disease infestation, and multi-peril crop insurance programs provide less of a safety net since they are based on average yields, which have fallen in the last several years. These factors accentuate the problem facing producers who have suffered repeated losses due to scab.

HEALTH EFFECTS AND TOXICITY OF *FUSARIUM* HEAD BLIGHT

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Molds are common contaminants of foods and feeds causing economic losses worldwide. The *Fusarium* genus is one of the most common molds and includes many mycotoxigenic species, such as *Fusarium graminearum*. *F. graminearum* is known to produce deoxynivalenol (DON, vomitoxin), 3-acetyldeoxynivalenol (3-ADON), 15-acetyldeoxynivalenol (15-ADON), nivalenol (NIV) and zearalenone. DON is a member of the trichothecene family of mycotoxins which contain some potent protein synthesis inhibitors, with DON being the most commonly detected trichothecene in grains all over the world. DON is known to cause acute toxic effects in animals and humans with symptoms of feed refusal, vomiting, diarrhea and weight loss. The mechanism of DON toxicity is still unknown. Further study of the effects of chronic exposure to DON is needed. Processing studies have been conducted to determine the fate of DON as it goes from grain to finished food product. Milling studies show that significant amounts of DON remain in all mill fractions from contaminated grains. Baking studies show DON to be very heat resistant. Chemical and physical treatments have been attempted to reduce levels of DON in contaminated grains, but their effectiveness and practicality is questionable. Surveys of retail food ingredients and products show that concentrations of DON are sometimes present at levels exceeding government guidelines. Currently, it would be impossible to prevent small amounts of DON from ending up in the diets of humans and animals, but with an understanding of why this mycotoxin occurs, what its effects are, and how to prevent exposure to it, the adverse effects of DON could be prevented. This review summarizes information related to the toxicological effects of DON and discusses implications on animal and human health.

Trichothecenes are sesquiterpene epoxides based on a parent 12, 13-epoxytrichothec-9-ene skeleton (1, 2), usually with one or more oxygen substituents. These compounds usually contain an epoxide at C-12 and C-13 which is an essential structural component for toxicity (1). The number of naturally occurring trichothecenes known today exceeds 80 (3). The most commonly detected trichothecenes in agricultural products include T-2 toxin, deoxynivalenol (DON), and diacetoxyscirpenol (1) with the most common one being DON (4). The DON derivatives, 3-acetyldeoxynivalenol (3-ADON) and 15-acetyldeoxynivalenol (15-ADON), are also commonly found (5), and may have similar, if not more potent, toxicity as DON (6, 7).

The earliest reported case of human mycotoxicosis thought to be linked to *Fusarium* mycotoxins occurred in Russia in the late 1800s and early 1900s. The disease state was called alimentary toxic aleukia (ATA) and was caused by consuming overwintered barley and millet (8). The symptoms of ATA include leukopenia, dermal necrosis, hemorrhaging, bone marrow destruction and eventual death (9). The disease became widespread in Russia in the 1930s and peaked in 1944 when 47 out of 50 Russian districts were affected (10). Molds found in the most contaminated grains included mainly *Fusarium* species, especially *F. poae* and *F. sporotrichioides*. Toxic compounds extracted from both the grain samples and molds were reported to be similar to steroids in structure. These were later found to be trichothecenes (mainly T-2 toxin); zearalenone was also detected (10).

Another outbreak of human mycotoxicosis occurred in Japan from 1943-1963 involving wheat, rice and barley and was called akakabi or red mold disease (11). Symptoms included nausea, vomiting, diarrhea, and hemorrhaging. *Fusarium* molds were found in the grain samples, with *F. graminearum* being the most prevalent species. This mold was shown to produce deoxynivalenol (DON) and nivalenol.

DON was first purified in Japan from moldy barley infected primarily with *Fusarium* species (12). When initially isolated, the toxin was given the trivial name Rd-toxin, then the chemical structure was established as the trichothecene 3α, 7α, 15-trihydroxy-12, 13-epoxytrichothec-9-en-8-one or deoxynivalenol (13). At about the same time in the United States the same toxin was isolated from corn contaminated with *Fusarium* that caused emesis in swine and was given the descriptive name of vomitoxin (14). Since then a great body of work has been done to find out more about this mycotoxin, but to date there are still many questions left to be answered about its occurrence, toxicity and production.

DON has been found in grains in North America, South America, Eastern and Western Europe, the Far East, Africa, and India (15, 16, 17, 18). Deoxynivalenol is produced by various species of *Fusarium* which are endemic to countries with temperate climates (19). Wheat, corn and barley, which are most affected by *Fusarium,* make up two-thirds of the world production of cereals (20). The United States, Canada, Romania and Russia have specified tolerance levels for DON (21). FDA guidelines in the United States have been set for concentrations of DON in human foods at 1 μg/g in finished wheat products destined to be consumed by humans (103).

DON has been associated with adverse reactions in livestock, especially swine, when present in feed materials. The symptoms include feed refusal, reduced weight gain, diarrhea and vomiting (22, 23, 24, 25). Humans are also affected by DON (18, 26). Evidence of this has been found in the Kashmir Valley in India where a segment of the population was affected by gastrointestinal disorders which were attributed to trichothecene contamination, predominately DON, of wheat based food products (27). Also, areas at high risk for esophageal cancer in China have been shown to have high concentrations of trichothecenes, mostly DON, in the staple food materials of these regions, such as corn and wheat (28). However, there is no direct evidence showing DON to be a carcinogen (29). Acute toxicosis due to DON has also been reported in China, Japan and Korea (30, 31). Deoxynivalenol may also have been used as part of a chemical warfare weapon including other trichothecenes in Southeast Asia around 1975, when reports of toxic yellow rain were made (32). Severe skin reactions to DON contaminated plant materials have also been observed in humans (33).

Feeding trials using DON have been conducted on many animal species. DON can be lethal at high concentrations, however, in animal studies there have been two main effects shown by DON; reduction of feed consumption (anorexia) when present at low concentrations, and vomiting (emesis) at higher acute doses (23, 34). Studies using swine have shown them to be quite sensitive to low amounts of DON (0.1-0.2 µg/g), showing feed refusal and concurrent weight loss (23). However, corn naturally contaminated with DON showed a greater effect than artificially contaminated corn, suggesting that other factors may be involved. Naturally contaminated grain samples may likely contain other toxins besides DON, such as 15-ADON (35).

Other feeding trials showed no overtly serious effects of DON in swine at concentrations at or lower than 2 µg/g, in poultry at or lower than 5 µg/g, and in dairy cattle at 1-6 µg/g in naturally contaminated feed (36). Turkey poults fed diets containing up to 75 µg/g DON (37) showed no significant acute affects. Huff *et al.* (38) reported an LD_{50} for DON in day old broiler chicks of 140 mg/kg body weight and no mortality until doses reached 70 mg/kg body weight. Feeding trials with naturally contaminated wheat using pregnant gilts have shown no apparent effects on pregnancy and lactation at DON concentrations of 3.29-6.2 µg/g (39, 40). Lambs fed diets containing 15.6 µg/g DON showed no differences in feed consumption, weight gain, and feed efficiency, nor in hematologic or serum biochemical variables from control lambs (41). Mink fed 1.18 µg/g DON from naturally contaminated wheat showed no significant effects on feed consumption or body weights over a 28-day trial period (42). Captive mallard ducks fed naturally contaminated wheat (5.8 µg DON/g) showed no evidence of taste aversion after 10 days and no obvious biological effects after 14 days (43).

Acute toxicity of DON in mice showed necrosis in the gastrointestinal tract, bone marrow and lymphoid tissues, and focal lesions in the kidney and cardiac tissues (44). Acute toxicity in broiler chicks showed extensive ecchymotic hemorrhaging throughout the carcass, disturbances of the nervous system and irritation of the upper gastro-intestinal tract (38) and, in other poultry, mouth ulcers, gizzard erosion, decreased feed consumption and weight gain, and increased mortality (45).

Not much is known about the chronic effects of low concentrations of DON in the diets of animals. At subchronic concentrations (10 µg/g) in mice, intestinal absorption of glucose was significantly reduced and may indicate that at concentrations of DON found in foods, intestinal transfer and uptake of nutrients may be impaired (46). A two year feeding study with B6C3F1 mice (0.1, 5 and 10 µg DON/g) resulted in decreased weight gain at higher DON concentrations, but no other significant biological effects were noted (47). Laying hens fed lower doses of DON (0.12-4.9 µg/g) showed no effect on weight gain, egg production, fertility, hatchability, or perinatal mortality; however, the incidence of chick developmental anomalies such as unwithdrawn yolk sac and delayed ossification increased (48). In growing pigs fed naturally contaminated oats, concentrations as low as 1.7 µg DON/g resulted in significant decrease in daily feed consumption (49).

The mechanism by which DON causes feed refusal and emesis is not yet known, however, some investigators have attempted to link it to alterations in neurotransmission. Species such as chickens, which are more resistant to trichothecene toxicity than other animals, were less likely to show significant alterations in brain amines upon exposure to the toxins (50, 51, 52, 53). The effect of DON on brain amine levels in swine has also been examined (54) and showed effects which were transmitter (specific amine), time and brain region specific. Ossenkopp *et al.* (55) demonstrated aversive postingestial effects of DON in rats injected with DON which induced a conditional taste aversion which was mediated by the area postrema in the brain.

Once administered orally or intravenously, DON does not appear to accumulate in the animal tissue after 24 hours (22, 56), or in the eggs of chickens (57, 58, 59), or in cows milk (60, 61). Once ingested, it does not seem to be bioactivated in the body to a more active form or converted to a less toxic compound via the hepatic mixed-function oxidase system (62). However, microorganisms present in the digestive tract may be able to metabolize DON to a less toxic form, i. e. deepoxydeoxynivalenol or DOM-1 (63, 64). This may help explain why ruminants and chickens are less susceptible to DON contamination in feeds. Chickens and ruminants may have similar microflora in their digestive tracts which grow anaerobically and produce volatile fatty acids by fermentation of fiber (65).

In some cases trichothecene-induced toxic states have been shown to persist even after the toxins were no longer found in the body (66). It has been stated that many features of the biological activity of trichothecenes are similar to those of the compounds generated by lipid peroxidation (67). Trichothecenes have been shown to cause an increase in the respiratory burst of macrophages in mice which may lead to the production of other toxic compounds via the peroxidation process initiated by reactive oxygen species in the blood (68). It has been shown that providing a diet high in antioxidants can reduce the toxic effects of DON at an acute dosage (28 mg/Kg b.w.) in rats (67), suggesting that the quality of animal diets may affect their susceptibility to DON toxicity.

Trichothecenes contain a biologically reactive epoxide group which can react with proteins and enzymes, and these toxins, including DON, have been shown to inhibit protein synthesis (18). The toxicology of DON has been reviewed by Rotter *et al.* (69). The action of DON can lead to immunosuppression in some test animals (70, 71, 72). Cytotoxic effects on human hematopoietic progenitors have been observed (73), and this may explain some of the effects seen in humans who have had trichothecene toxicosis. Immunosuppression may predispose animals and humans to infectious diseases (70).

Immunostimulation has also been observed during dosing of animals with DON. It has been shown in mouse model systems that ingestion of DON leads to an elevation in serum immunoglobulin A (IgA) levels with concomitant lowering in levels of IgM and to mesangial IgA deposition in the glomerulus of the kidney. This simulates human IgA nephropathy, a kidney disease known as Berger's disease, which is a common form of glomerulonephritis with no known cause (74, 75, 76). It has been suggested that this increase in IgA secretion may be a result of overproduction of interleukins, induced by the protein synthesis inhibition effect of DON (77, 78). The effect of DON on IgA levels also appears to be more pronounced in the male sex of the test animals (75, 79, 80). Levels of IgE have also been shown to be raised in mice even after withdrawal of DON from the diet (81). There has been no effect seen on the levels of IgG in mice fed 12 weeks on a 25 μg/g DON diet (74).

Foods and feeds may contain many components and therefore, potentially, many types of mycotoxins. Other trichothecenes and zearalenone (82, 83, 84), as well as fumonisins and aflatoxins (85, 86, 87) have been found mixed with DON in foods and feeds. Deoxynivalenol has been examined for additive effects with other mycotoxins. When examined with ochratoxin in broiler chick feed there were only slight interactions, described as less than additive and in some cases antagonistic (88). Growing pigs treated with DON and/or aflatoxin showed no additive effects from the mycotoxin combination (89). However, broiler chickens fed DON and aflatoxin did show an additive toxic effect (90). Deoxynivalenol's co-occurrence with aflatoxin may synergize the carcinogenicity of aflatoxin (91). When DON was examined in combination with T2-toxin (92) there was a significant additive effect on reduced weight gain and the incidence of oral lesions in broiler chicks. Friend *et al.*(93) found an additive effect between DON and T2-toxin in the performance of young pigs. A study by Trenholm *et al.* (94) showed no large interactions between DON and zearalenone for weight gain and feed intake in gilts, however, DON did appear to antagonize the estrogenic effect of zearalenone, and the effects of DON were slightly enhanced in combination with zearalenone. Combining DON and fumonisin B_1 in feed led to additive toxic effects in growing barrows (95). The *Fusarium* metabolites sambucinol (SAM), 15-ADON, 3-ADON, culmorin (CUL), and dihydroxycalonectrin (DHCAL) (at a 2 μg/g) were tested with DON (at a 6 μg/g) on growing pigs (96); none of these showed any additive effects. However, when DON was examined with CUL, SAM and DHCAL in a caterpillar bioassay there were synergistic interactions (97).

Although not as acutely toxic as some trichothecenes, DON is of considerable concern because of its prevalence in food and feed materials. Deoxynivalenol may be even more important as a public health risk than currently thought due to its presence at chronic concentrations in the diet along with other mycotoxins and toxins. Much more research needs to be done to assess the risk of this mycotoxin to human health.

DON is the most common trichothecene mycotoxin found in commodity grains, therefore the potential exists for it to end up in finished foods and feeds. Many food products, from bread and snack foods to beer, may contain at least trace amounts of DON. There is a need to determine the concentrations of DON that may end up in finished products to help assess the amount of DON entering the human and animal diet. In a review by Scott (98) it was stated that vomitoxin (DON) had been shown to be the most heat stable mycotoxin tested in food processing experiments at that time, mainly bread baking experiments. Most processing studies since than have also shown DON to be very stable.

Truckses *et al.* (99) analyzed 60 breakfast cereals, 9 corn syrups, and 14 beer samples from grocery stores for DON. Deoxynivalenol was detected in about 60 % of the breakfast cereals with an average concentration of 100 ng/g and none was detected in corn syrup or beer. Abouzied *et al.* (100) surveyed 92 food samples made from United States grain grown in the drought year of 1988; they found DON in 50% of the samples overall with 83% of the corn cereals, wheat flour muffin mixes, rice cereals, and corn meal muffin mixes being positive and 50% of the oat cereals, wheat and oat based cookies and crackers, corn chips, popcorn, and mixed-grain cereals being positive. Mean concentrations of DON were 4.0 μg/g in positive samples with a minimum concentration of 1.2 μg/g and a maximum concentration of 19 μg/g. Brumley *et al.* (101) found DON in 54 out of 57 wheat samples (mean 3.6 μg/g), 48 out of 50 corn samples (mean 0.3 μg/g), 44 out of 50 flour samples (mean 0.11 μg/g), 45 out of 50 corn meal samples (mean 0.08 μg/g), and 14 out of 21 snack food (chips or biscuits) samples (mean 0.11 μg/g). Truckess *et al.* (102) did a survey of wheat products including 272 white flour samples, 90 whole wheat flour samples and 163 wheat bran samples. They found 10.3% of the white flour samples, 15.6% of the whole wheat flour samples and 12.3 % of the wheat bran samples contained more than 1 µg DON/g. A survey done by Patel *et al.* (86) of ethnic foods in the U.K. showed µg/g levels of DON in cereal products, spices and canned foods; other mycotoxins such as aflatoxin, zearalenone and fumonisins were also found. This evidence shows that DON can be a common contaminant of human foods, and levels exceeding government guidelines (1 µg DON/g in foods destined for human consumption) (103) do occur.

The significance of DON retention in processed foods is only beginning to be realized. The levels by which the mycotoxin can be expected to be reduced during food processing needs further study. Variations in analytical methods need to be accounted for, and better, more accurate methods need to be developed. The toxic effects of chronic levels of DON need further study as well to determine safe levels which can be allowed to occur in foods and feeds. Currently, it would be impossible to prevent small amounts of DON from ending up in the diets of humans and animals, but with an understanding of why this mycotoxin occurs, what its effects are, and how to prevent exposure to it, the adverse effects of DON could be prevented.

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SYMPOSIUM – THE IMPACT OF EXOTIC PLANTS ON NATURAL AND AGRONOMIC ECOSYSTEMS

AN OVERVIEW OF EXOTIC PLANT INVASIONS

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EXOTIC PLANTS OF THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

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EFFECTS OF PHYTOTOXINS ON THE GROWTH AND PHYSIOLOGY OF LEAFY SPURGE (*EUPHORBIA ESULA* L.)

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AN OVERVIEW OF EXOTIC PLANT INVASIONS

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INTRODUCTION

In recent times, numerous and ever-accelerating changes in ecosystems have been occurring throughout North America. These changes are the result of increasing influences of man to provide food, fiber and fuel for expanding human populations. With disruptions of natural ecosystems by human activities, have come deliberate and accidental introductions of many insect pests, plant pathogens, and weed species (Table 1). Once established, exotic species often significantly reduce crop, range, pasture, and forest productivity, despite expensive pesticide treatment programs being implemented.

Table 1. Number of major invading weed species, insect species and plant pathogens of U.S. pastures, forests and croplands and their origin.

Origin	Weed	Insect	Plant pathogen
Europe	39	42	19
Eurasia	35		
Africa	1	1	
Asia	8	4	1
Tropical America	9	12	13
Mediterranean	3		
Other	8	19	18
Total	103	78	51

Source: (1).

The following discussion will emphasize exotic plant species in the Northern Plains region. I will attempt to briefly introduce the problem, who are the exotic species, how they gain access, and why they pose problems.

DISCUSSION

Background

What is an invasive exotic plant? According to Cronk and Fuller (2), an invasive plant is "an alien plant spreading naturally (without the direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure or ecosystem processes". Exotic plants are introduced by human activities into areas outside their native range. In their natural habitats, they were held in check by natural ecosystem processes such as competition, predation and disease. Released into new environments, the natural population controlling forces of these exotic species are limited to non-existent.

The origin and number of major weed and insect species, and plant pathogens in United States pastures, forests and croplands are summarized in Table 1. This summary is only a small percentage of the total as there are approximately 4,000 exotic plants listed as introduced into the United States of which nearly 10% are considered pest species (3).

Species

Just who are these invasive plant species? A total of only 12 plants are on the noxious weed list of North Dakota (Table 2). In addition, another 30 species are listed in the four state region of South Dakota, Nebraska, Wyoming and Montana. A review of these 40 plus noxious weed species indicates each was introduced into North America. Surprisingly, only one grass is on this list, quackgrass (*Agropyron repens*). Many range or plant ecologists might expect Kentucky bluegrass (*Poa pratensis*), cheatgrass (*Bromus tectorum*) or other annual bromes (*Bromus* spp.) and possibly smooth bromegrass (*Bromus mollis*) to fit this list, at least in some instances. These are all exotic and invasive species on many of our rangelands, pastures and wildlands in the Northern Plains yet have various levels of value as livestock forage. Also lacking in these noxious weed lists are native invasive plants. On many range and pasturelands in this region, western snowberry (*Symphoricarpos occidentalis*), various sagebrushes (*Artemisia* spp.), silverberry (*Eleagnus commutata*), and aspen (*Populus tremuloides*) are also considered invasive shrub species.

Table 2. North Dakota state noxious weed list.

Common name	Scientific name	Listed by
Absinth wormwood	*Artemisia absinthium*	1971
Canada thistle	*Cirsium arvense*	1891
Diffuse knapweed	*Centaurea diffusa*	1996
Field bindweed	*Convolvulus arvensis*	1935
Hemp (marijuana)	*Cannabis sativa*	1971
Hoary cress	*Cardaria* spp.	1935
Leafy spurge	*Euphorbia esula*	1935
Musk thistle	*Carduus nutans*	1971
Perennial sowthistle	*Sonchus arvensis*	1971
Purple loosestrife	*Lythrum solicaria*	1996
Russian knapweed	*Centaurea repens*	1935
Spotted knapweed	*Centaurea maculosa*	1983

Source: (4).

Modes of Entry

As stated previously, exotics have gained entry into North America by various modes. The most common modes are in ship ballast, in crop seed, by animal import, in soil of nursery stock, and deliberate introductions. In our early history, great sailing ships were used to transport people and goods between the new and old worlds. Ballast, rocks and soil, was loaded into ships to allow them to sail smoothly through the seas. At the end of trips, the ballast was dumped near or on shore along with any stowaways, such as weed seeds. Immigrants also brought their prized crop seed to the new world which was often contaminated by weed seed. Imported livestock also carried weed seed in hair, wool or on hooves. Nursery stock was also frequently imported and carried weed seed in the soil surrounding the roots. Lastly, many weeds have been deliberately introduced into North America as ornamental or crop species.

Once introduced, numerous human influences sped the entry and dispersal of these weeds into range, pasture and croplands. Widespread heavy grazing pressure by domestic livestock and fencing, which restricted the natural movement of grazing animals, depleted many grassland ecosystems creating sites for weed invasion. Fire, a natural grassland ecosystem maintenance factor, was nearly eliminated causing many fire intolerant invasive species to spread onto the prairies. Cultivation and abandonment of many former grasslands acted as repositories for numerous invasive weed species. Dispersal of invasive weeds throughout North America has been aided by the high mobility of man, domestic livestock, and feed supplies. Road sides, rail lines, shipping canals, and cattle and feed shipping have all been corridors or vectors of weed species dispersal.

Natural ecosystem disturbances also aid the invasion and dispersion of weed species. Drought or flood are consistent ecosystem disturbances in the Northern Plains. Approximately 2 of 10 years in eastern and 4 of 10 years in western North Dakota will ecologically be considered drought years. Wildfires create natural openings for plant invasions. In addition, grazed areas surrounding water sources are prime sites for exotic plant invasions. Before European settlement, even wildlife species were noted as having large and fluctuating populations grazing on the plains. Meriwether Lewis in 1805 and 1806 (5) made many diary notations on the lands, plants and animals of the Northern Plains. For example, on Sunday April 14, 1805 near New Town, ND, Lewis wrote "The low grounds are wide, the moister parts containing timber, the upland extremely broken, without wood, and in some places seem as if they had slipped down in masses of several acres in surface". On Monday April 20, 1805 near Fort Peck, Montana, he wrote "The country is broken and irregular..., nine-tenths of the ground being totally destitute of wood and covered with a short grass, aromatic herbs and an immense quantity of prickly pears". For animals, Lewis noted on Wednesday May 8, 1805 near the Milk River, Montana "As usual we are surrounded by buffalo, elk, white and black-tailed deer, beaver, antelopes, and wolves". Lewis' diary entries across the Northern Plains consistently document hot, dry conditions, minor and massive erosion events, and increasing and/or invading plant species such as sages, tansy's, thistles, onions, short grasses, and prickly pear cactus. He also noted potential evidence of overgrazing especially surrounding scarce water supplies by large and fluctuating populations of Northern Plains herbivores.

Associated Problems

Why do these exotic invasive plant species pose problems to the Northern Plains? There are numerous reasons for this starting with their basic biological characteristics. Most exotic invasive plants exhibit early and rapid growth and early flowering giving them a competitive advantage for light, moisture and other scarce growth resources. They exhibit different growth forms depending upon the ecosystem present, and a high degree of phenotypic plasticity. For example, exotic plant species typically exhibit a variety of short and root growth forms (upright vs. prostrate; fibrous vs. top) and compete under a wide range of light regimes, and environmental conditions such as moisture, soils, nutrients, slope, etc. Invasive plant species also have a high reproductive success. They set seed under wide variations of temperature and day length, produce numerous seeds that may be viable over many years, and reproduce by vegetative means also. Exotic plant species generally exhibit avoidance and tolerance mechanisms to defoliation also. They often avoid being grazed by having awns, spines, thorns, chemical irritants or poisons and short growth forms. Tolerance to defoliation is provided by low growing points, ability to tiller, and high regrowth potential. Think of leafy spurge as an example. Leafy spurge has early and rapid spring growth, grows from water's edge to dry, barren buttes, produces numerous seeds per stalk that can germinate over ten years, sprout from crown and rhizome buds, have large, well-developed fibrous and top root systems and contains a milky white latex in its tissues that proves to be a chemical irritant to cattle and may be allelopathic to competing plant species and their seedlings.

Exotic plant invasions may modify habitats by replacing a diverse system with a near monoculture, alter the water, fire and soil nutrient regimes, decrease the productivity of forage supplies, and even alter erosion and sedimentation processes. Spotted knapweed (*Centaurea maculosa*) invasion of a bunchgrass site in Montana resulted in a lower total herbaceous foliar and ground cover, with resultant increases in runoff of 56% and sediment yield of 192% following simulated rainfalls (6). Economically, knapweeds have been estimated to have a direct impact of over $14 million annually to Montana's economy resulting from reduced personal income, lost cash outlays due to reduced livestock sales, reduced wildlife-associated recreation and reduced soil and water conservation (7). Leafy spurge, in North Dakota, was reported to decrease herbage production by as much as 75% (8) and reduce annual livestock sales and production expenditures by over $23 million (9).

CONCLUSION

In conclusion, I'll ask the question, what do we do now? The answer to that question is we take or continue to take action concerning exotic invasive plants. The main actions we can take and you may hear more of in this symposium are: 1) implementing education and awareness programs, 2) increased legislation, 3) prevention of introduction and dispersal, and 4) continued research and implementation of integrated control programs against invasive species.

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EXOTIC PLANTS OF THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

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INTRODUCTION

One of the major objectives of the National Park Service is to maintain the structural and functional integrity of a particular area in as nearly a pristine condition possible. However, most national parks are surrounded by communities totally unlike those contained within the park (Janzen 1983). Many of the surrounding communities contain species of exotic or non-native plant species that invade a park and interact with the native residents. Exotics are, in most cases, ecologically, economically and/or aesthetically undesirable. An increase in exotic plant species in Theodore Roosevelt National Park (TRNP) generated considerable concern regarding the effects that exotics may have on the native communities. A 3-year study was initiated in the summer of 1991 to determine the extent, distribution, and ecological impact of exotics in TRNP (Butler and Trammell 1995). During the course of this study, leafy spurge (*Euphorbia esula*) was recognized as one of the more troublesome exotic plant species in the Park. In 1997, while participating in an effort to develop a digitized vegetation map for TRNP, the impact of leafy spurge infestations on landscape-level species diversity was evaluated. The purpose of the present paper is to synthesize the results of the two investigations. Specifically, we will address the number and distribution of exotic plant species in TRNP, the ecological impact of four selected exotic species on the native biota, and the influence of leafy spurge on local and landscape-level native plant species diversity.

METHODS

A systematic search for exotics in both the North and South Units was conducted during the 1991, 1992, and 1993 field seasons (Butler and Trammell 1995). Specific study sites selected and surveyed represented the range of natural habitat types within the Park. Areas adjacent to developed roads, trails, water tanks, and prairie dog towns were also examined. Foliar cover of exotic species was estimated from a large number of 20 cm x 50 cm quadrats randomly placed in each habitat type using the Daubenmire cover class system (Barbour et al. 1987). Several sites were selected to examine the effect of exotic infestations on aboveground biomass of native species and habitat utilization by bison, elk, and deer (Trammell and Butler 1995). During the 1997 field season as part of the vegetation mapping project, we evaluated native plant species composition and foliar cover within 10m x 10m plots subjectively placed in communities not infested with leafy spurge in the South Unit. These data were compared to information collected from plots located in the same plant community type but heavily infested with leafy spurge. We calculated similarity coefficients and Shannon Diversity Indices, based on foliar cover, for 1997 infested and noninfested plots. To examine the historical impact of leafy spurge infestations on native species diversity, we compared the 1997 information to pre-1984 data which were collected and published by previous researchers in the Park.

RESULTS AND DISCUSSION

Thirty-six species of exotic plant species were recorded during the 3-year survey in both the North and South Units of the Park (Table 1). The majority of the species recorded were annuals or biennials and were infrequent constituents of the native community. These species appeared to have little or no ecological impact. Several species were common but occurred at low densities. Ten species were consistently recorded in both Units and for all three field seasons. Seven species were recorded only during one field season in the North Unit while 13 species were recorded in the South Unit. Japanese brome (*Bromus japonicus*) and yellow sweet clover (*Melilotus officinalis*) were the most frequently occurring species in the North Unit. The dominant exotic species found in the South Unit included Japanese brome, smooth brome (*B. inermis*), downy brome (*B. tectorum*), leafy spurge, and yellow sweet clover. Areas adjacent to established roads had the highest species richness within both units of the Park (Butler and Trammell 1995). Smooth brome was the most dominant exotic species recorded along roadsides for both units. Secondary species along roadsides included yellow sweet clover and Kentucky bluegrass. Some of the exotics found along roadsides may be slowly migrating outward into non-infested grasslands. Common dandelion, yellow sweet clover, Kentucky bluegrass (*Poa pratensis*), Japanese brome, and crested wheatgrass (*Agropyron cristatum*) were generally the most frequently occurring species along hiking trails (Butler and Trammell 1995). Areas around developed watering facilities were dominated by yellow sweet clover, Japanese brome, and

Kentucky bluegrass. Several species of exotics were restricted to disturbed sites such as trails, watering facilities, and prairie dog towns. They included henban (*Hyoscamus nigar*), tumble mustard (*Sisymbrium altissimum*), small-seeded smal flax (*Camelina microcarpa*), and Russian thistle (*Salsola iberica*). Japanese brome, smooth brome, downy brome, and leafy spurge were consistently found in non-disturbed habitats within the Park.

The effects of Japanese brome, smooth brome, downy brome, and leafy spurge on biomass production were evaluated for all three sampling years by clipping aboveground biomass within 20 cm x 50 cm quadrats (Table 2). Total biomass, which included native and exotic plant species, was significantly higher on infested sites compared to noninfested for all four species of exotics. Total biomass of native species was substantially reduced by heavy infestations of the four exotic plant species for all three years. Heavy infestations of exotics, especially leafy spurge, reduces the carrying capacity of the area for the bison, elk, and deer that inhabit the Park (Trammell and Butler 1995). Much of this loss in leafy spurge infested sites is attributed to decreased forage production of native vegetation and avoidance of infested sites. A reduction in carrying capacity because of exotic plant infestation may result in overgrazing and overbrowsing of many sites considered exotic free, thereby creating a possible invasion point from surrounding infested sites and accelerating the invasion process.

Because of the extensive nature of leafy spurge infestations, this species was selected to evaluate the effect of heavy infestations on species diversity in several selected community types (Table 3). Species richness was significantly reduced ($P<0.05$) by an average of 46% (standard deviation = 9%) in seven out of the ten communities compared. The *Artemisia cana*, *Calamovilfa longifolia*, and *Juniperus horizontalis* community types were impacted the most by heavy infestations of leafy spurge. The *Salix exigua* community, considered a successional community along the floodplain for the Little Missouri River, was the least influenced by leafy spurge. An almost identical pattern was observed when Shannon's diversity indices (H′) were compared between infested and noninfested community types. However, the *Pascopyrum smithii* community type was an exception. Although species richness was significantly different between infested and noninfested sites, diversity values were similar. This is probably a reflection of an increase in evenness among the native species on sites heavily infested with leafy spurge.

Species composition between selected community types evaluated during the 1997 vegetation mapping project was similar to pre-1984 information. Data collected by previous researchers in the area before 1984 are considered to be prior to heavy infestations of leafy spurge. Percent similarity in community composition between the pre-1984 and 1997 noninfested sites averaged 75 percent (Table 4). The *Populus deltoides* community type showed the greatest similarity (90%) while the *Juniperus scopulorum* community type exhibited the least (68%). The differences can probably be attributed to such factors as different methods used by the various researchers, and seasonal and yearly fluctuations in species composition. Percent similarity was reduced an average of 36% and 39% when infested communities evaluated in 1997 were compared to sites examined prior to1984 and during 1997, respectively. The relatively high degree of similarity between the pre-1984 and 1997 data indicate that the reduction in species richness on sites heavily infested with leafy spurge, that were evaluated in 1997, can be attributed almost directly to leafy spurge and not random fluctuations in species composition, site differences, or different sampling procedures. Further, we suspect that the majority of native species not present on infested sites are those that occur infrequently or in low abundance on noninfested sites (data not shown). The majority of the native species still present on heavily infested sites are the more frequent species; however, their overall contribution to the community has been substantially reduced (Table 2).

CONCLUSIONS

The diversity of exotic plant species in Theodore Roosevelt National Park is relatively high. However, the majority of the species recorded in the Park occur infrequently or at low densities, and have no apparent ecological impact. Japanese brome, downy brome, smooth brome, and leafy spurge are common exotics throughout the Park. These four species are dominating and displacing many of the native species. Leafy spurge is, without question, the major exotic threatening the structural and functional integrity of the native communities in the Park and throughout the region.

Table 1. Exotic plants of Theodore Roosevelt National Park prepared from the preliminary Park flora, Stevens (1963) and Flora of the Great Plains (1986). Units and years recorded are listed separately for each exotic 1=1991, 2=1992, 3=1993). Plant nomenclature follows that of Flora of the Great Plains (1986). List modified from Butler and Trammell (1995).

FAMILY/SCIENTIFIC NAME	COMMON NAME	NORTH UNIT	SOUTH UNIT
AMARATHACEAE			
Amaranthus retroflexus	Redroot pigweed	3	
ASTERACEAE			
Artemisia absinthium	Absinthse wormwood	1	1
Carduus nutans	Musk thistle		1
Centaurea maculosa	Spotted knapweed		2
Cirsium arvense	Canada thistle	1,3	1
Lactuca serriola	Prickly lettuce	1,2,3	1,2,3
Taraxacum officinale	Common dandelion	1,2,3	2,3
Tragopogon dubius	Goatsbeard/Salsify	1,2,3	1,2,3
BORAGINACEAE			
Asperugo procumbens	Catchweed	1	
Lappula echinata	Blue stickseed	1,2,3	1,2,3
BRASSICACEAE			
Camelina microcarpa	False flax	1,3	2,3
Capsella bursa-pastoris	Sheperd's purse	1	1,2
Descurainia sophia	Flixweed	2,3	2,3
Sisymbrium altissimum	Tumbling mustard	2	2
Thlaspi arvense	Pennycress	3	
CHENOPODIACEAE			
Chenopodium album	Lamb's quarters	1,2,3	1,2,3
Kochia scoparia	Burning bush/kochia	1	1
Salsola iberica	Russian thistle	1,2,3	1,2,3
CONVOLVULACEAE			
Convolvulus arvensis	Field bindweed	1,3	1,3
ELAEAGNACEAE			
Elaeagnus angustifolia	Russian olive		2
EUPHORBIACEAE			
Euphorbia esula	Leafy spurge	1,2,3	
FABACEAE			
Medicago sativa	Alfalfa		1,2
Melilotus alba	White sweet clover	1,2,3	1,2
Melilotus officinalis	Yellow sweet clover	1,2,3	1,2,3
Oxalis lupalina	Black medic		3
MALVACEAE			
Malva rotundifolia	Dwarf mallow	1	
PLANTAGINACEAE			
Plantago major	Common plantain		3

Table 1. (continued)

FAMILY/SCIENTIFIC NAME	COMMON NAME	NORTH UNIT	SOUTH UNIT
POACEAE			
Agropyron cristatum	Crested wheatgrass	1,2	1,2,3
Bromus inermis	Smooth brome	1,2,3	1,2,3
Bromus japonicus	Japanese brome	1,2,3	1,2,3
Bromus tectorum	Downy brome	1,2,3	1,2,3
POACEAE (continued)			
Poa compressa	Canada bluegrass	1	1,2
Poa pratensis	Kentucky bluegrass	1,2,3	1,2,3
Setaria viridis	Green foxtail	1,2	1
POLYGONACEAE			
Rumex crispus	Curled dock		2
SOLANACEAE			
Hyoscyamus niger	Henbane		3

Table 2. Mean aboveground biomass (g/m^2; n = 10, 20 cm x 50 cm quadrats within a year within a level of infestation) of exotic plant species clipped at peak biomass (early August) for 1991, 1992, and 1993 in Theodore Roosevelt National Park, North Dakota (NOINF = noninfested, INF = approximately 100% of sampling unit covered with selected exotic plant). Data modified from Butler and Trammell 1995.

	Japanese Brome		Downy Brome		Smooth Brome		Leafy Spurge	
	NOINF	INF	NOINF	INF	NOINF	INF	NOINF	INF
1991								
Native Species	167.9	43.0	128.9	56.7	164.8	6.3	126.9	28.8
Exotic Species	0.0	227.2	0.0	183.4	0.0	260.6	0.0	262.2
1992								
Native Species	118.3	14.5	118.7	9.1	81.6	1.8	86.8	12.9
Exotic Species	0.0	149.3	0.0	79.4	0.0	166.0	0.0	301.3
1993								
Native Species	161.5	45.1	156.7	33.5	191.5	10.5	190.0	30.0
Exotic Species	0.0	335.0	0.0	340.3	0.0	512.5	0.0	225.0

Table 3. Mean (standard error) species richness and Shannon's diversity index (H') within 10 communities infested with leafy spurge (*Euphorbia esula;* leafy spurge was excluded in the calculations) and noninfested plant communities in Theodore Roosevelt National Park, North Dakota sampled during the 1997 growing season. Effects of infestation within each plant community were compared using a 2-sample *t*-test.[a]

	Species Richness			H′		
Community Name	**Noninfested**	**Infested**	***t***	**Noninfested**	**Infested**	***t***
Stipa comata	21.3 (1.38) n = 12	12.4 (1.03) n = 9	4.28 (P=0.001)	2.78 (0.10) n=12	2.08 (0.12) n= 9	4.56 (P=0.001)
Artemisia cana	16.3 (1.74) n=8	7.5 (0.87) n=9	4.63 (P=0.001)	2.22 (0.18) n=8	1.43 (0.12) n=9	3.55 (P=0.0032)
Calamovilfa longifolia	21. 2 (3.42) n=5	9.0 (1.73) n=4	2.92 (P=0.02)	2.43 (0.29) n=5	1.35 (0.30) n=4	2.60 (P=0.04)
Fraxinus pennsylvanica	31.0 (4.81) n=11 n=11	23.9 (4.49) n=8 n=8	1.04 (P=0.31; Δ=25.0)	3.09 (0.30) n=11	2.40 (0.23) n=8	1.71 (P=0.11; Δ=1.46)
Symphoricarpos occidentalis	12.8 (1.78) n=9	10.8 (1.55) n=9	0.85 (P=0.41; Δ=8.1)	1.39 (0.09) n=9	1.39 (0.12) n=9	0.05 (P=.96; Δ=0.52)
Salix exigua	12.6 (1.39) n=7	11.8 (1.24) n=5	0.39 (P=0.70: Δ=7.63)	2.28 (0.28) n=7	2.11 (0.12) n=5	0.49 (P=0.63; Δ=1.38)
Juniperus scopulorum	26.0 (1.88) n=9	15.2 (1.02) n=5	4.05 (P=0.001)	2.80 (0.22) n=9	2.8 (0.17) n=5	2.44) (P=0.03)
J. horizontalis	32.1 (1.18) n=9	16.6 (1.63) n=5	7.76 (P=0.001)	2.99 (0.13) n=9	2.44 (0.10) n=5	2.93) (P=0.01)
Populus deltoides	21.5 (1.70) n=8	15.0 (1.43) n=6	2.81 (P=0.02	2.94 (0.23) n=8	2.26 (0.09) n=6	2.88) (P=0.01)
Pascopyrum smithii	18.0 (1.26) n=10	9.8 (1.52) n=8	4.21 (P=0.001)	2.28 (0.13) n=10	1.69 (0.26) n=8	1.62 (P=0.12; Δ=1.22)

[a]Effect size (Δ) was estimated when $P > 0.05$, where effect size was the minimum detectable difference ($\alpha = 0.05$, $\beta = 0.10$, n = number of 10 x 10 m plots in infested and noninfested sites; Zar 1996).

Table 4. Percent similarity between Pre-1984 and 1997 community data for selected communities infested (INF) and not infested (NI) with leafy spurge in Theodore Roosevelt National Park, Medora, North Dakota.

	Percent Similarity		
Community Name	**Pre-1984(NI)/1997(NI)**	**Pre-1984(NI)/1997(INF)**	**1997(NI)/1997(INF)**
Stipa comata	73	39	35
Artemisia cana	72	52	59
Fraxinus pennsylvanica	75	52	56
Symphoricarpos occidentalis	72	39	26
Juniperus scopulorum	68	50	48
J. horizontalis	72	39	47
Populus deltoides	90	64	59
Pascopyrum smithii	75	39	36

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EFFECTS OF PHYTOTOXINS ON THE GROWTH AND PHYSIOLOGY OF LEAFY SPURGE (*EUPHORBIA ESULA* L.)

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INTRODUCTION

Leafy spurge (*Euphorbia esula* L.) is an Eurasian plant species that was introduced onto the North America continent in the late 1800's. Since that time, leafy spurge has become well established and currently infests extensive areas of rangeland throughout much of the Northern Great Plains. Much of the weed control effort focuses on conventional control/eradication programs utilizing herbicides, an approach that is expensive and therefore limited to areas of high productivity.

Alternative approaches to control leafy spurge include biological insect control and behaviorally encouraging lambs and goats to preferentially graze on leafy spurge.

Leafy spurge dominates and displaces many native plant species in a variety of habitats. Belcher and Wilson (1989) found that leafy spurge significantly decreased the frequency of five common native mixed-grass species in Manitoba, Canada. Within portions of the North Dakota Badlands, native grasslands deteriorate further when heavy infestations of leafy spurge cause shifts in habitat utilization by native ungulates (Trammel and Butler, 1995). While many native plants are displaced by leafy spurge, small everlasting (*Antennaria microphylla* Rydb.), a common native forb, is phytotoxic to and resists encroachment by leafy spurge. It is unlikely that competition alone explains the inhibition of leafy spurge due to the fact that the plant is a deep rooted vigorous clonal species, whereas small everlasting is shallow rooted and grows relatively slowly. In the field, small everlasting inhibited the growth of leafy spurge while soil removed from around small everlasting had a similar effect. In this same study, plant and soil extracts of small everlasting inhibited leafy spurge seed germination and seedling development. Extraction and isolation of compounds from small everlasting yielded hydroquinone (HQ), arbutin (a monoglucoside of HQ), caffeic acid, and benzoquinone (Manners and Galitz, 1985).

Allelopathy refers to the process by which certain compounds (allelochemicals) produced by plants are released into the environment where they can interfere with the growth of other plants. In direct contrast to competition, allelopathic interactions involve the addition of chemical substances into the environment. It has been well documented that interference by certain donor species, particularly by the release of phenolic compounds, is related to disruption of certain physiological processes of target plants (Einhellig, 1986). The allelopathic influence of HQ on the growth of soybean has been linked to changes in plant water relations (Barkosky, 1988). One primary mechanism of interference may be a perturbation of cell membranes which would likely influence plant water relations and lead to a reduction in overall plant growth. Determination of intermediate or secondary physiological effects, including interactions with plant hormones, ion uptake, mitochondrial respiration, and photosynthesis, could lead to further insight into the mode of action of allelochemicals.

Insight into long term changes in plant water relations, can be obtained by determining carbon isotope ratios (^{13}C: ^{12}C) in plant tissue. Diffusional limitation of CO_2 through the stomata decrease discrimination against the heavier isotope, while factors influencing enzyme activity tend to increase the discrimination (O'Leary, 1988).

DISCUSSION

When leafy spurge cutting are exposed to HQ within a hydroponic system, they exhibit visually stunted growth, chlorotic leaves, and black slimy roots. Measured growth parameters such as leaf area, root weight, and total plant weight are also significantly reduced in plants treated at various concentrations of HQ. Also, I have found that leafy spurge plants treated with HQ experience significantly higher diffusive resistances and lower rates of transpiration when compared to untreated plants. Also, long-term exposure to HQ results in plants that discriminate less against ^{13}C over the duration of the treatment indicating a limitation to the diffusion of CO_2 through the stomata. These experiments clearly demonstrate that exposure to HQ inhibits the growth of leafy spurge at the whole plant level. Furthermore, a disruption in plant water relations appears to be the primary mode of action which leads to reductions in overall growth. In earlier work, I determined that treatment with 0.25 mM HQ increased stomatal resistance, lowered transpiration, and reduced the growth of soybean seedlings (Barkosky, 1988). Data from the current experiment suggest that leafy spurge cuttings exposed to HQ experienced similar changes in stomatal function early in the experiment.

In conclusion, experiment documents some of the phytotoxic effects of HQ on the physiology and growth of leafy spurge. This and other experiments tend to support the field observation that small everlasting resists encroachment by leafy spurge.

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COMMUNICATIONS

UNDERGRADUATE

INITIATION OF A LONG TERM INVERTEBRATE SAMPLING PROJECT ON THE SHEYENNE RIVER

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Introduction Our goal is to develop a long range biomonitoring project based on the macroinvertebrate fauna of the Sheyenne River. The Sheyenne River, which begins in central North Dakota and winds its way south through Lisbon before emptying into the Red River near Fargo, passes through a primarily agricultural area. Because of this, the river is subjected to many factors that contribute to a high organic content in the water. While there have been studies on the hydrogeology and water chemistry of this area, there has been little work on the biological integrity of the river. Macroinvertebrate sampling is recognized as an important tool in determining the relative health of a river and, with proper background data, identifying changes in that health. Our purpose was to begin compiling data for the area of the Sheyenne River near Valley City. In addition, we are sampling tributaries to the Sheyenne to examine any variations in the macroinvertebrate fauna of these tributaries and the Sheyenne.

Methods Five sites along the Sheyenne were sampled in the late summer to fall of 1997. Four of these sites were sampled twice. Two of the five sites were located upstream of Valley City, one was located within Valley City, and two were located downstream of Valley City. In addition, three sites located on tributary streams to the Sheyenne were sampled once. Two of these tributaries were located upstream of Valley City and the third entered the Sheyenne within the limits of Valley City. Sampling was done primarily with D-frame aquatic nets. Both kick sampling and jab sampling techniques were used. In addition, bottom sediments were scooped up with D-frame nets and examined for macroinvertebrates. All samples were placed on a portable screen and washed with river water. The macroinvertebrates were collected from the screen and placed in 70% Ethanol. Various snags and other debris were also examined and macroinvertebrates collected from them. Samples were labeled in the field and brought back to the lab for identification and storage. Identification of the macroinvertebrates was done in January and February of 1998. Identification was done to the lowest taxon possible. In most cases this was the genus level with some to the species level. Various metrics of biotic integrity were calculated for the sites. The metrics were compared to those established for Montana wadable streams located in the plains ecoregion (1).

Results The Taxa Richness metric, which records the total number of macroinvertebrate taxa found in an area, for the five sampling sites along the Sheyenne ranged from 12 - 20 with an average of 15.2. Taxa Richness for the tributaries ranged from 11 - 17 with an average of 15.0. Using the assessment criteria for metric scoring established for Montana wadable streams in the plains ecoregion, these Taxa Richness numbers indicate a moderate level of impairment in water quality (1). A Taxa Richness of 24 or greater is considered a non-impaired river. It is interesting to note that the lowest scores were obtained from the sites located within Valley City. However, the site with the highest Taxa Richness was located just 2 miles downstream from Valley City. Examinations of the number of Ephemeroptera, Plecoptera, and Trichoptera index (EPT index) showed similar results. The range for sites along the Sheyenne was 3 - 7 with an average of 5.0. These numbers also fall within the moderate level of impairment category. EPT index for the tributaries was lower, however, with a range of 0 - 3 and an average of 1.67. This falls in the severe impairment category. Several other metrics were determined with the majority indicating at least a moderate level of impairment.

Discussion Our data shows that the Sheyenne River is currently in a state of moderate impairment of water quality according to macroinvertebrate bioassay procedures. This does not come as a surprise given the agriculture nature of our area and the high organic content of the river. Our use of data from Montana streams may be questionable, but we could find no other references that we felt were similar to the condition of the Sheyenne. We hope to collect enough data in the years to come to determine our own reference metrics. With the current impacts on the Sheyenne River, and the possible impacts in the future, we hope this information will be useful in discussions of the health of the Sheyenne.

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COMMUNICATIONS

PROFESSIONAL

AGING BLACK-TAILED PRAIRIE DOGS (*CYNOMYS LUDOVICIANUS*) BY HUMERUS LENGTH AND WIDTH

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Many techniques have been used over the years to age mammals. These methods often entail measuring and evaluating changes in the skull, teeth, or long bones that occur with increasing age. Aging by the degree of epiphyseal closure of the humerus or femur has been used in a variety of species since the 1940's. Aging by epiphyseal closure can be subjective, however, and might vary between researchers. Additionally, after complete closure, the method is not useful. In this study, we evaluated the efficacy of using humerus length and width as a means of aging black-tailed prairie dogs (*Cynomys ludovicianus*).

Humeri (left) from 237 black-tailed prairie dogs, collected from Billings County, North Dakota, were used in the analysis presented here. Damaged humeri or those where the epiphysis detached from the diaphysis during the cleaning process were not included. Humeri were boiled, cleaned, and air-dried. Measurements were taken with a Mitutoyo digimatic caliper. Greatest humerus length was measured from the most distal point to the most proximal point. The humerus width was measured at the widest portion of the diaphysis that was proximal to the head of the humerus. All humeri were assigned an age (i.e., pup, yearling, 2 years, 3 years) based on a combination of eye lens weight and skull and teeth characteristics (1). Some older animals (3+ years) were grouped with the 3-year-olds because they could not be differentiated from them.

Results indicated that humerus length and width were highly correlated ($r = +0.93$, $n = 237$); therefore, the results of the analyses were similar for both variables. We used a one-tailed t-test because males were expected to be larger than females, and animals from older age classes were expected to be larger than those from younger age classes. Sexual dimorphism was evident in every age class in both length and width. However, the difference was not significant between the male and female pups ($P > 0.05$) whereas $P < 0.0001$ for yearling and 2-year-old age classes and $P < 0.01$ for 3-year-old age classes. Average length and width were significantly different between pup and yearling age classes for both males and females ($P < 0.0001$). In older age classes, the differences between age classes were not as pronounced. Lengths and widths from male yearlings were not significantly different ($P > 0.05$) from those of male 2-year-olds, whereas they were in females ($P < 0.02$). Analyses comparing 2-year-olds to 3-year-olds were mixed. However, sample sizes were small and analyses were probably not reliable. In conclusion, aging prairie dogs by humerus length and width holds promise, especially in the younger age classes. This method is less subjective than epiphyseal closure and is more readily replicable between researchers. Further analyses will divide age classes into smaller subsets based on age in increments of days instead of years.

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SURVIVAL AND POPULATION STRUCTURE OF A GUNNISON'S PRAIRIE DOG (*CYNOMYS GUNNISONI*) POPULATION IN COLORADO

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Gunnison's prairie dogs (*Cynomys gunnisoni*) have a relatively small distribution, being limited to the "Four Corners" area where Colorado, Utah, Arizona, and New Mexico meet. Long-term studies on Gunnison's prairie dogs are relatively few, possibly because of this species' reported susceptibility to plague (*Yersinia pestis*). The study described here is part of a long-term study addressing various aspects of population ecology. This paper will specifically address survival.

Female prairie dogs are usually more philopatric, i.e., remaining in or close to their natal areas as adults, than males which often disperse in the spring after spending their first winter in their natal areas. For our study, no distinction could be made between emigration and mortality. Hence, "survival" refers to those animals that were recaptured in consecutive years.

Our study site was located in Archuleta County, Colorado, approximately 21 km northwest of Pagosa Springs. The area was approximately 2.3 km in altitude. A 3-ha portion of the prairie dog colony was trapped during the summers of 1991 through 1997 using Tomahawk live-traps baited with rolled oats and covered with a roofing shingle. Traps were placed so as to saturate the areas around the burrow openings and periodically moved when all animals in an area appeared to have been captured. All areas of the 3-ha portion were trapped for approximately 7-10 days during each year except 1997 when efforts were curtailed due to weather constraints and illness.

Each captured prairie dog was weighed, aged, sexed, ear-tagged, and marked with a unique design using Nyanzol D dye. Reproductive condition and capture location were also recorded before the animal was released.

In 1996, a Global Positioning System (Trimble Model Pro-XL) was used to map the entrances to the prairie dog burrows in the 3-ha study area. General habitat data describing the area around each burrow entrance were also recorded with the Pro-XL.

From 1991 through 1997, approximately 350 prairie dogs were ear-tagged. Based on trapping records, 3 social (i.e., breeding) groups appeared to exist within the 3-ha study area. Female survival was usually greater than that of males for both pup and adult age classes. Between any 2 consecutive years, survival from pup to yearling was often less than 8% for males, whereas female survival reached up to 25-33% for 3 of the 6 intervals. Overall, if a female pup reached the age of 1 year, its chances of surviving to the next year increased.

For the approximately 170 captured males, only 9 were captured for 2 consecutive years and 1 additional animal for 3 years. For the approximately 180 captured females, 22 females were captured for 2 consecutive years; additionally, 3 females were captured for 3 consecutive years, 1 for 4 years, 2 for 5 years, and 2 for 6 years. None of the 4 oldest females were captured in 1997, indicating probable death. Potentially, population turnover and survival could greatly influence genetic diversity of Gunnison's prairie dog populations.

EARTHWORM POPULATION ESTIMATES IN NORTH DAKOTA (LUMBRICIDAE)

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Populations of earthworms for the northern prairie region of central United States have not been well established. Deibert and Utter (1) looked at three agricultural sites in eastern North Dakota and found populations that ranged from 190 to 740 per square meter (cocoons plus earthworms). In southern Alberta Canada, Clapperton et. al. (2) observed higher populations of *Aporrectodea caliginosa* (Savigny) under zero-tillage systems versus conventional. They also observed that over 90 percent of the earthworms and cocoons sampled were in the top 15cm of the soil profile for endogeic species found at this site.

A population survey from randomly selected, primarily agricultural, and positive earthworm sites was performed in North Dakota in early to late spring from 1990 to 1997. Each site had 3 cores (20.3cm diameter by 15.0cm depth) taken to determine populations. Subsamples were taken with a spade to determine mature adult species present. Core samples were hand sorted to determine number of earthworms present. The soil was washed through a series of 5mm, 2mm and 1mm sieves to find cocoons or any juveniles missed in hand sorting. All earthworms from the core samples and mature adult subsamples were fixed with 10% formalin for identification using a guide by Schwert (3).

Table 1. Earthworm Populations in North Dakota. (Utter and Deibert, 1998)

Site†	Core Frequency	Juveniles‡	Adults¶	Cocoons	Total
	— no. —	Number / meter square			
CRP	15	454	64	119	637
Notill	47	202	79	116	397
Plow	13	38	29	55	122
Sweep	20	71	73	74	218
Grass	15	169	105	47	321
Trees	2	107	200	740	1047

† CRP= Conservation Reserve Program farmland with grass-legume cover, Notill= tillage system with high surface residue cover, Plow= plow system with low surface residue cover, Sweep= chisel-sweep with medium surface residue cover, Grass= grass areas mainly along field edges or road ditches, Trees= shelterbelt on a wildlife management area in southwestern North Dakota.

‡ Lumbricidae in the life stage between hatching and the presence of genital markings.

¶ Lumbricidae with recognizable genital markings i.e. clitellum, tubercula pubertatis, genital tumescence, etc.

The primary species found at all sites were *Aporrectodea tuberculata* (Eisen) and/or *Aporrectodea trapezoides* (Duges) which corresponds with prior findings by Utter et. al. (4) as being the most common species in North Dakota. Increasing number of earthworms were found with decreasing tillage and increasing residue cover, which follows research results found nationally and internationally. A very high total population in the tree site was unexpected, with a large percentage (70.7%) being cocoons versus adults. This indicates high adult activity prior to sampling and a need for more population sampling at deeper depths in forested areas in the state. Population data is from only positive lumbricidae sites and does not take into account areas of the state with no earthworms. Data for the grass site does not include native prairie since earthworms were not generally found in these areas. It is speculated that the high efficiency of native grasses in utilizing the limited soil moisture available in the region affects earthworm presence or survival.

The authors thank the North Dakota Game and Fish Department, numerous private land owners, and the State Agricultural Experimental Research Stations for their cooperation in this study.

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A STUDY OF FECAL COLIFORM BACTERIA LEVELS IN THE SHEYENNE RIVER SEGMENT THAT PASSES THROUGH VALLEY CITY, NORTH DAKOTA

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The United States Environmental Protection Agency (EPA) has established guidelines for evaluating the bacteriological quality of both drinking water and water used for recreational purposes. These criteria include the maximum number of fecal coliform organisms permitted per 100 milliliters of water. In 1995 and 1996 fecal coliform levels in the Sheyenne River exceeded the EPA maximum for recreational water. This occurred on a number of sampling days during the open water season (1). The Sheyenne river has been viewed as an important recreational resource for the Valley City area and for the state as a whole. According to health department data, the river poses a recreational health hazard at times during the open water season.

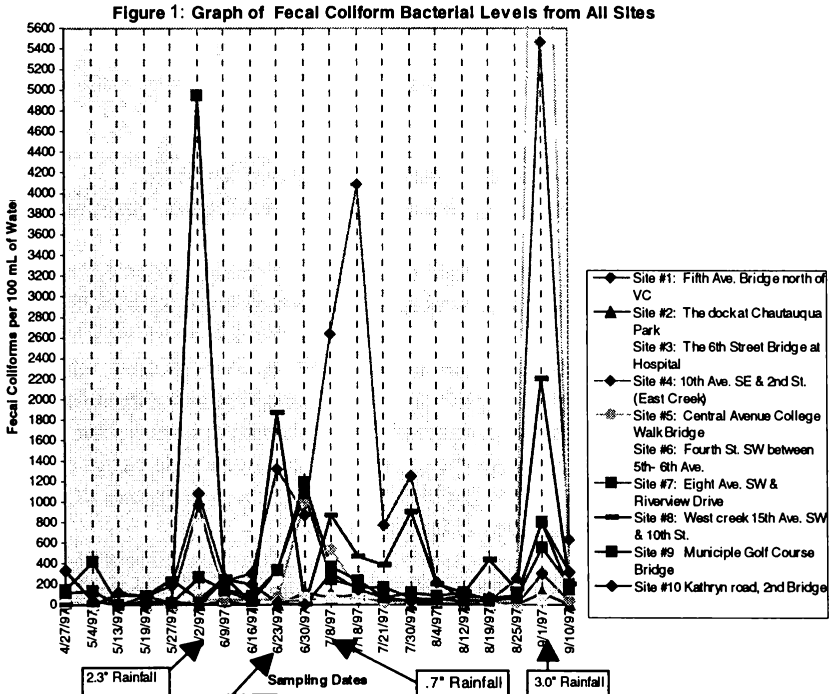
This study monitored fecal coliform levels in the Sheyenne River; before it entered and after it exited Valley City, at various places within Valley City, and in two creeks just before they entered the Sheyenne river. Study objectives were to determine the levels of fecal coliforms during the open water season, and to try to identify potential sources of fecal coliform bacteria that were entering the River.

Samples were taken at ten sites selected on the basis of their position within the study area and their accessibility for sampling. Each site was sampled weekly from April 27 through September 10. All samples were processed using EPA approved techniques for establishing fecal coliform bacterial levels. Multiple dilution filtrations were not carried out, so some counts exceeded or were under the recommended EPA range for accuracy.

Results showed that rainfall and runoff significantly increased fecal coliform levels in the river and that the two creeks added significant numbers of fecal coliform bacteria to the river. The pumping of raw sewage into the river raised the fecal coliform counts above acceptable levels immediately downstream of the pumping site (even when the river water volume was high). The study indicated that fecal coliform bacteria were entering the river from sites both within the City and from outside the City (Figure 1). The study also demonstrated a lack of suspicious or elevated fecal coliform levels below the sewage lagoon discharge site when the pumping of processed wastewater was in progress. River levels and dam discharge appeared to effect fecal coliform levels only in relation to the water volume in the river which served to dilute the bacteria when volume was high.

If the Sheyenne river is to consistently meet United States health standards for recreational water uses, sources of fecal coliform bacterial pollution need to be identified and managed.

Figure 1: Graph of Fecal Coliform Bacterial Levels from All Sites



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THE AGAMID LIZARD *TINOSAURUS* FROM THE MEDICINE POLE HILLS LOCALITY (EOCENE-CHADRONIAN), SOUTHWESTERN NORTH DAKOTA

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The Medicine Pole Hills Local Fauna (1,2,3) has produced remains from the agamid lizard *Tinosaurus*. This fauna from southwestern North Dakota has been determined to represent the very earliest Chadronian based upon mammalian specimens previously reported from the locality (4).

The presence of *Tinosaurus* at this late Eocene Chadronian locality is the latest report for the occurence of this genus in the fossil record. At present there are five species of *Tinosaurus* recognized as being valid, two from North America and three from Asia (5), all being Paleocene through late-early Eocene in age. Other specimens, not identified to species, are found in the early-middle Eocene of Europe and Asia (5). Fragments referable to *Tinosaurus* have been reported from the upper Eocene formations of California (6), but are Uintan in age (J. Lilligraven, pers. comm. 1998).

The occurrence of *Tinosaurus* in this Chadronian-age fauna demonstrates the presence of this agamid throughout the Eocene in North America and may indicate the possibility of a new species.

The referred specimen PTRM-2038 is a fragment of bone from the right dentary with two tricuspid, acrodont teeth. The anterior tooth measures 0.87 mm in width and the posterior tooth 1.06 mm, as measured at their widest point. The teeth are laterally compressed with three antero-posteriorly aligned cusps, the median being the tallest at 0.95 mm for the anterior and 1.12 mm for the posterior tooth. The teeth are separated with a spacing of 0.27 mm at the narrowest point and 0.35 mm at the level of the jaw parapet. The total space occupied by both teeth on the dentary fragment equals 2.07 mm. The anterior tooth extends 0.50 mm above the parapet of the jaw and the posterior tooth 0.64 mm. Both teeth exhibit sub-equal lateral cusps that would taper to sharp occlusal edges. The bases of the teeth are broad and fused to the dorsal margin of the dentary at a slight angle. The above description agrees with that reported for this genus (5,7,8,9). The presence of lateral cusps on both teeth indicates the specimen originated from the middle, or more posterior portion, of the dentary (7).

Specimen PTRM-2038 compares most favorably to the North American species *T. stenodon*, but the space occupied by the teeth on the dentary is smaller. It does not compare to the more closely spaced teeth of *T. pristinus* or the overlapping teeth reported for the Asian species *T. asiaticus* and *T. lushihensis*.

Though the fossil *Tinosaurus* is poorly known, the referred slightly worn specimen clearly exhibits the morphological characteristics and provides us with new biostratigraphical information for this genus.

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EVOLUTION OF SOUTHWEST NORTH DAKOTA'S DRAINAGE NETWORK

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Introduction: Clausen (1) redefined North America's central region physiographic provinces to better understand glacial history. Using new definitions he then described five phases of regional meltwater flooding which resulted in present-day drainage patterns (2,3). This paper reviews southwest North Dakota evidence which documents these meltwater movements.

Phase I: Cypress Hills Stage: Southwest North Dakota evidence associated with Alsask (2) and Mondak (3) river deposition of Cypress Hills stage alluvium include White River Group (Oligocene) and other Tertiary sediments. Alsask and Mondak flood routes were toward an ice sheet breach where meltwater floods flowed back onto the ice sheet to join the then supraglacial Midcontinent River (this situation may have resulted when the Midcontinent River captured a south-flowing supraglacial river). At peak meltwater flood times secondary Mondak River flood routes spilled east from the primary flood route to flow across southwest North Dakota, to cross the ice sheet surface at less well-developed, but similar breaches, and to join the south-flowing Dakota River. These secondary flood routes carved and then partly backfilled deep bedrock valleys.

Phase II: Flaxville Stage: The Flaxville stage occurred when the Midcontinent River and its tributary Alsask and Mondak rivers sliced deeper valleys into the ice sheet and adjacent bedrock surfaces. During this stage the Mondak River reworked alluvium originally deposited during the Cypress Hills stage (today this reworked alluvium caps the Yellowstone-Redwater drainage divide). Also, Mondak River secondary flow across southwest North Dakota to the Dakota River, having the shorter route, enlarged eastern ice sheet breaches, which diverted more and more flow southeast across the then high-level bedrock surface and which eroded deep southeast-oriented headcuts into the ice sheet surface and adjacent bedrock surface.

Phase III: Southwest River Stage: The Flaxville stage evolved into the Southwest River stage when accelerated ice sheet melting increased meltwater flooding and further opened up southeast-oriented breaches. One major Southwest River flood route surrounded the Black Hills and continued east through a deep breach which had opened up at the Southwest Ice Sheet's south end. In northwest South Dakota and southwest North Dakota southeast-oriented headcuts eroded headward, and as they became interconnected, lowered the bedrock surface. Present-day buttes are remnants of those headcut walls. Headcut locations can be identified by outlining most southeast-oriented drainage basins (e.g. southeast-oriented Cannonball basin).

Phase IV: Southwest River Dismemberment Stage: Midcontinent River dismemberment (1, 4) then enabled new and deeper northeast-oriented headcuts to erode headward to capture what had been southeast-oriented flow. Spectacular elbows of capture can be observed in western South Dakota, including along the Cheyenne River at its confluence with the Belle Fourche River and south of the Black Hills, and in North Dakota along the Cannonball, Heart and Knife Rivers. For example, the northeast-oriented Heart and Knife headcuts eroded headward and captured southeast-oriented floods along routes now used by: 1) Big Muddy Creek, 2) southeast-oriented Knife River, 3) Spring Creek, and 4) Antelope Valley, among others. The south headcut wall is the Russian Springs Escarpment and north and east of the Escarpment is the headcut floor.

Also, two northeast-oriented headcuts eroded headward from what had been the Alsask River breach. Mondak River alluvium (now capping the Yellowstone-Redwater divide) formed a protective "caprock" and split Mondak and Alsask River flow. East of this Mondak alluvium a shallow Mondak River headcut first captured Southwest River floods to establish the north-oriented Little Missouri alignment. But the deeper Lincoln Valley headcut captured this north-oriented flow and a branch captured flow which reached Hofflund Flats while another branch eroded west to capture all north-oriented flow (modern Little Missouri route). The Yellowstone-Powder River breach (Little Muddy Valley) then captured all Southwest River flow which had been moving to the Little Missouri. The Beaver Creek-Yellowstone River, Little Beaver Creek-Powder River, and Boxelder Creek-Powder River drainage divides all document this capture. West of the Mondak alluvium, Medicine Lake breach headcut branches eroded south and west to form the Missouri and Milk River valley system (2).

Phase V: Missouri Valley Formation Stage: Southwest North Dakota's drainage network was finalized when climates changed, meltwater floods froze and blocked all Southwest Ice Sheet breaches. Unable to flow northeast, meltwater and other drainage, which was still flowing in newly-developed northeast-oriented valleys south and west of the Ice Sheet, was ponded and water spilled over drainage divides along the Southwest Ice Sheet's outer margin. In this manner segments of what had been northeast-oriented drainage routes became connected to form North Dakota's present-day Missouri River Valley.

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NORTH DAKOTA AND OTHER "GLACIAL" LAKES EXPLAINED AS SLACK WATER FEATURES

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Introduction: Clausen (1, 2, 3, and 4) interpreted central North American escarpments, through valleys, ice stagnation moraines, regional drainage networks and other landforms to have formed during the rapid meltdown of what had to be North America's only Cenozoic ice sheet. This interpretation does not recognize most ice margins hypothesized by previous workers (5) to have formed ice-marginal "glacial" lakes. Yet, lacustrine sediments, deltaic deposits, shoreline features and other evidence all document the existence of these "glacial" lakes. This paper reinterprets the origin of "glacial" lakes Agassiz, Souris, Hind, Regina, and Missoula by viewing key evidence using the rapid meltdown hypothesis perspective.

Slack Water "Lake" Model: The rapid meltdown hypothesis explains most "glacial" lake evidence by immense slack water areas which inundated valleys and lowlands adjacent to primary meltwater flood routes. Primary flood routes were scoured by meltwater flood movement, however, active deposition of lacustrine and other sediments occurred in quieter slack water "lake" areas. Slack water "lake" levels were controlled by discharges along primary meltwater flood routes as well as by secondary outlets which formed where slack water "lakes" overtopped drainage divides. Shoreline features, lacustrine and deltaic sediments, through valleys and other evidence can be used to reconstruct meltwater flood routes and discharge history.

"Glacial" Lake Agassiz: "Glacial" Lake Agassiz formed when slack water associated with a progression of Midcontinent River dismemberment stages inundated the Agassiz Trench and adjacent lowlands. Prior to dismemberment the immense Midcontinent River had flowed southeast to the Gulf of Mexico. Major tributaries included the south-flowing Agassiz River and proto-Assiniboine River (flowing south between the Turtle and Moose Mountains). Midcontinent River dismemberment occurred because the Agassiz River reversed direction and began to flow north to Hudson Straits. During North Dakota's initial Midcontinent River dismemberment stage floods were diverted north through what is now the Red River Valley (the present-day Sheyenne and Maple River U-turns document this reversal). The second stage occurred when melting opened up a new west-to-east flow route between what are now the Turtle Mountains and Riding Mountain and enabled the proto-Assiniboine River to make a U-turn around the south end of Riding Mountain (present-day Assiniboine River route). This route opened up a shorter Midcontinent River flood route, with the Midcontinent River making a U-turn in north central North Dakota to flow west and north of the Turtle Mountains (the present-day Souris River U-turn documents this route). Many North Dakota and Minnesota "Glacial" Lake Agassiz features resulted during this second dismemberment stage as slack water inundated the Agassiz Trench and at peak flood times overflowed to the south and east. Many subsequent "Glacial" Lake Agassiz features developed as slack water inundated large areas of Manitoba and adjacent Saskatchewan when the Midcontinent River main flood route was diverted northeast through what is today the Saskatchewan River Valley.

"Glacial" Lakes Souris, Hind and Regina: "Glacial" Lake Souris initially formed when the Midcontinent River "cut-off" its north central North Dakota U-turn and flowed east along a route used now by the Antler River. Slack water inundated lowlands which had been eroded by the Midcontinent River just prior to this cut-off. "Glacial" Lake Hind formed when important Midcontinent River flood routes developed along what is now the Qu'Appelle-Assiniboine River route, with slack water inundating adjacent lowlands which had been eroded by the previous flow route. The Pembina Valley developed as an initial "Glacial" Lake Hind outlet, but slack water also drained directly northeast to what is now the Assiniboine Valley (forming the abrupt Souris River right turn south of Brandon). "Glacial" Lake Regina formed when slack water filled the former Midcontinent River floor south and east of the present-day North Saskatchewan River U-turn, after further ice sheet melting diverted the main Midcontinent River flood route northeast (Saskatchewan River route). "Glacial" Lake Regina overflowed to the southeast and east to cause additional flood events which further altered North Dakota landforms (6).

"Glacial" Lake Missoula: Most other "glacial" lakes can be explained in a similar manner. For example, in Montana "Glacial" Lake Missoula can be explained by damming of the Mondak River, which after events described by Clausen (3), was diverted west by uplift and headward erosion of the Clark Fork Valley. Damming was caused by immense meltwater floods (late stages of the Great Divide River flood route) which flowed south through the Purcell Trench and then west across Washington to erode the Columbia River Gorge and form well-described Channeled Scablands catastrophic flood features.

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USING SOIL MAPS TO BETTER DEFINE THE HERMAN STRANDLINE IN GRAND FORKS COUNTY

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The Herman strandline is the oldest of the well-preserved Lake Agassiz strandlines (1), and as such is of particular interest to some researchers. The Herman is largely absent from the southern 10 miles of the Grand Forks County geologic map (2). Because parent material is one of the soil forming factors, one might expect that soil maps may be helpful in mapping surficial geology. Lindholm (3) has mapped the geology of the Culpeper Basin using soil maps. This study compared the geologic map of Grand Forks County (2) to soil maps in the Grand Forks County Soil Survey (4) to determine if the soil maps could be used to map the Herman strandline in southern parts of the county where it is currently unmapped (Figure 1).

The southern-most mapped section of the Herman strandline was located on the Grand Forks County geologic map (2) and then found in the Grand Forks County Soil Survey (4). From there, it was traced south to the county line using the method employed by (5). The Hecla and Embden soil series, used to trace the Herman, can form in sediments deposited on delta plains or beaches (4). The areas of these soils traced in this study were interpreted to represent strandline deposited materials because: A) they were present at and extended beyond the southern most extent of the Herman strandline as mapped by (2), B) the long, narrow morphology of these soils mimics expected strandline morphology, and C) the north-northwest trend of these soils is expected of the Herman strandline. During the soil mapping of Grand Forks County, no concerted effort was made by the soil scientists to locate, map, or correlate the Lake Agassiz strandlines (6). Therefore, places mapped as Hecla or Embden in the areas we would expect to encounter the Herman strandline are simply a natural result of the mapping process, and do not represent any bias towards attempting to identify the strandline.

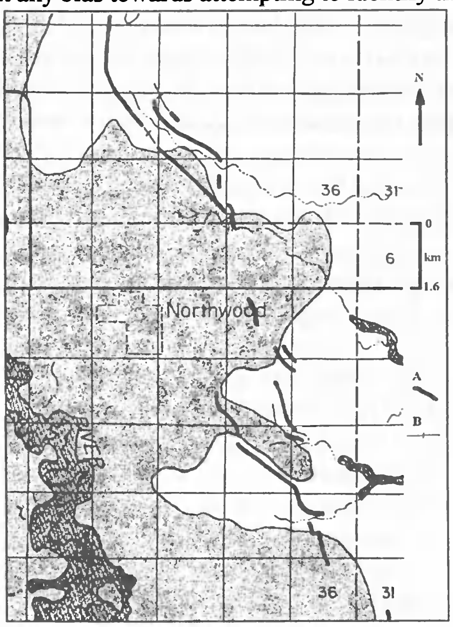

Figure 1 – The Herman strandline in southern Grand Forks County as mapped using soils information.
A – mapped by soils
B – mapped by Hansen and Kume (2)
Base map from Hansen and Kume (2)

There are a number of possible reasons that the Herman strandline shows up in some places on the soil maps but not on the geologic map. The geologists were probably mapping only landforms when they mapped the strandlines. If an area did not show noticeable positive relief, such as described by (1), they probably did not map it as a strandline. Although much soil mapping is also done by landform-soil relationships, the soil mappers used shallow probe samples if they could not differentiate the soils by landform relationships (6). Therefore, they may have found strandline-indicative soils in areas that did not display much local relief. In addition, the soil maps are at a scale of 1:20,000, whereas the geologic map is at 1:126,720. Because of this, more detail would be expected on the soil maps.

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ASSOCIATION OF DOMINANT SOMATOTYPE OF MEN WITH BODY STRUCTURE, FUNCTION AND NUTRITIONAL STATUS

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Humans of different body size, shape and structure demonstrate unique capacities for exercise and physical training (1). A clear association between physical performance and somatotype, and between structure and somatotype, has been established (2). However, because performance is an indirect measure of physiological function, an association between somatotype and function has only been implied. There have been few attempts to explore the interactions among somatotype and the physiological response to exercise or to nutritional status.

We examined the association among structural (somatotype and body composition), functional (cardiopulmonary responses to a standardized physical work capacity test on a cycle ergometer), and nutritional (plasma lipid, lipoprotein fractions and trace element concentrations, together with other selected blood biochemical variables and nutritional intake data) aspects of exercise performance of 63 men aged 18-40 years just before their participation in controlled live-in studies of trace element metabolism. Data were grouped by somatotype dominance and analyzed by ANOVA with Tukey contrasts.

Table 1. Structural, Nutritional and Functional Variables (mean ± SE) Listed by Somatotype Dominance

	Endomorphs n= 14	**Mesomorphs n = 30**	**Ectomorphs n = 19**
Body weight, kg	$87.7^{b} \pm 2.3$	$78.0^{b} \pm 2.9$	$67.3^{a} \pm 1.8$
Fat-free mass, kg	$63.9^{b} \pm 1.8$	$62.0^{b} \pm 1.9$	$56.5^{a} \pm 1.5$
Body Fat, %	$24.4^{b} \pm 2.0$	$17.8^{a,b} \pm 0.9$	$14.0^{a} \pm 0.8$
Body cell mass, g/cm	$0.837^{b} \pm 0.120$	$0.821^{b} \pm 0.062$	$0.695^{a} \pm 0.074$
Hemoglobin, g/L	180 ± 27	159 ± 3	157 ± 2
Ferritin, mg/L	51.0 ± 10.7	93.0 ± 11.2	80.0 ± 28.5
SOD, U/g Hb	$2654^{a} \pm 102$	$3298^{a,b} \pm 127$	$3479^{b} \pm 192$
Plasma Cu, mmol/L	13.7 ± 0.6	13.0 ± 0.3	14.3 ± 0.6
Plasma Fe, mmol/L	21.8 ± 1.3	20.8 ± 1.1	22.2 ± 1.7
TIBC, mmol/L	53.9 ± 2.47	50.3 ± 1.6	51.0 ± 1.9
Serum Mg, mmol/L	0.83 ± 0.02	0.81 ± 0.02	0.88 ± 0.02
Plasma Zn, mmol/L	13.0 ± 0.5	13.0 ± 0.3	13.3 ± 0.5
TCHOL, mmol/L	4.63 ± 0.30	4.37 ± 0.16	4.53 ± 0.21
HDL, mmol/L	$1.04^{a} \pm 0.11$	$1.26^{a,b} \pm 0.06$	$1.47^{b} \pm 0.08$
Energy intake, kcal/d	2866 ± 356	3391 ± 287	2828 ± 258
Energy, kcal/kg FFW/d	55.2 ± 5.6	50.9 ± 6.2	50.4 ± 7.5
Cu intake, mg/d	1.60 ± 0.25	2.38 ± 0.31	2.01 ± 0.3
Fe intake, mg/d	19.0 ± 2.1	24.0 ± 4.4	19.0 ± 2.1
Mg intake, mg/d	335 ± 26	432 ± 55	405 ± 74
Zn intake, mg/d	13.4 ± 1.2	15.8 ± 1.7	13.3 ± 2.2
Power, W	202 ± 11	210 ± 7	209 ± 9
VO_2, mL/kg/min	$34.2^{a} \pm 2.6$	$39.2^{a,b} \pm 1.6$	$41.6^{b} \pm 1.7$
RER	$1.08^{a} \pm 0.02$	$1.14^{a,b} \pm 0.02$	$1.17^{b} \pm 0.03$
Blood lactate, mM/L	$4.8^{a} \pm 0.7$	$5.9^{a,b} \pm 0.3$	$6.6^{b} \pm 0.4$

[a,b]Different superscripts indicate statistically different ($p<0.05$) means among dominant somatotypes.

The structural analysis found that the ectomorphic (ECTO) group had the lowest body weight, the least fat-free weight and body cell mass, was taller than the mesomorphs (MESO), and had less body fat than the endomorphs (ENDO) (Table 1). The MESO group was the shortest. Although all nutritional values were within the normal range, the ECTOs had increased blood superoxide dimutase (SOD) activity and high density lipoprotein (HDL) concentrations, ENDOs had the lowest values, Though not significantly so, the ECTOs had the highest mean plasma Cu and serum MG. When corrected for fat-free mass, the ENDOs had the highest mean energy intake. When corrected for energy intake, the ECTOs had the highest intake of Mg. At the end of exercise, at peak power output, the ECTOs had the highest oxygen consumption per unit body weight and the highest respiratory exchange ratio (RER). Mean end-exercise ventilation to peak oxygen consumption ratio (VE/VO_2) and blood lactate concentrations were also highest for the ECTOs; these findings were consistent with similar peak power being achieved with less muscle mass. Because all groups produced similar peak power output, it may be concluded that somatotype is associated with an altered metabolic response during progressive exhaustive exercise. This finding apparently is related to body cell mass; the amount of energy producing tissue (i.e., muscle) is less in ectomorphy.

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ANALOG CONFORMATIONS AS AN EXPLANATORY FACTOR IN PREDICTING BINDING TO THE REGULATORY SUBUNIT OF CAMP DEPENDENT PROTEIN KINASE

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cAMP-dependent protein kinase is a tetrameric enzyme, R_2C_2, composed of two regulatory (R) and two catalytic (C) subunits. Binding four molecules of cAMP causes dissociation of the catalytic subunits which then become active. Two major regulatory subunit isoforms are known (RI alpha and RII alpha) and each has two cAMP binding sites (A and B) that have distinct analog specificities and kinetic properties (1). The X-ray crystal structure of the type I alpha R subunit has been determined (2). There are also cGMP-dependent protein kinases homologous with the cAMP dependent protein kinases which differ in their cyclic nucleotide-binding specificities.

As part of an effort to better understand the molecular basis of the differences in the specificities of these protein kinases we have made extensive use of analog binding data from the literature to create 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 (Tripos) and INSIGHT II (Biosym/Molecular Simulations). Preliminary results of these studies have been presented (3).

In our preliminary studies the torsion angle between the purine ring and the ribosyl moiety was set at the actual angle found for cAMP in the B-site of RI (50.2°); further work was performed to modify the database using analog conformations minimized to conform to the known structure of the binding pocket to produce more interpretable CoMFA maps (4).

As previously reported (5), two analogs from the Ogreid paper (8-aza(OH) cAMP and cXMP) were consistently poorly predicted; exclusion of these invariably markedly improved the model. These analogs predict poorly because their preferred conformations deviate greatly from the *syn* conformation required for binding to cAMP dependent protein kinase.

The realization that poor predictions of binding for 8-aza(OH) cAMP and for cXMP were the result of their preferred conformations caused us to investigate the conformations of the other analogs in our database by performing simulated annealing runs on all the analogs; this procedure finds global energy minima. Using these results we calculated the percentage of *syn* conformers based on Boltzman distributions (6) for each analog to use as an additional explanatory factor for predictions of binding constants.

For use as a second explanatory factor related to conformation, the energy penalties for altering the conformation of each analog from its preferred torsion angle to the optimum torsion angle of the binding site were also calculated.

The results of using these additional factors for performing QSAR's are shown below:

Binding Site	Add. Exp. Var.	X-validated r^2		Opt. # of components in model	
AI:	None	.565		6	
	% *syn*	.554		6	
	% *syn* + Tor. En.	.478		7	
BI:	None	.489	(.512)	4 or 5	(6)
	% *syn*	.657	(.685)	4	(5)
	% *syn* + Tor. En.	.709	(.727)	5	(6)

All r^2's are based on 79 analogs and CoMFA's as an explanatory variable. X-validated r^2 's are 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.

Using the additional explanatory factors based on conformation improved predictions for the B site of the RI type subunit but did not improve predictions for the A site. Note that a range of torsion angles of approximately 35° is allowed in the A site while a narrower range (15°) is allowed in the B site. This more stringent range of torsion angles suggests that this factor should be more important as an explanatory factor for the B site.

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DIETARY VANADIUM AFFECTS CARBOHYDRATE AND THYROID METABOLISM IN THE BB RAT

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Since 1971, circumstantial evidence for the nutritional essentiality of vanadium (V) has appeared. However, this evidence has been questioned. Thus, stronger evidence for essentiality has been sought, this includes finding a specific biochemical role for V higher animals. The three-way 2x2x2 factorially arranged experiment described here was conducted to obtain further evidence to support the suggestion that V has a role that affects thyroid metabolism (1). The variables were deficient and adequate dietary V, or about 2 ng and 500 ng/g diet; low and luxuriant dietary iodine (I), or about 50 ng and 25 µg/g diet; and type of rat, either diabetes-prone or diabetes-resistant BB/Wor rat. Each treatment group contained eight rats which were fed ad lib their appropriate casein-ground corn-corn oil based diet (1) for 90 days before being fasted overnight and decapitated subsequent to ether anesthesia and cardiac exsanguination with a heparin-coated syringe and needle. Plasma triiodothyronine (T_3), thyroxine (T_4) and serum lactate dehydrogenase (SLD) were determined by using commercially available kits. Pancreatic amylase (PA) was determined by a published method (2). Data were statistically compared by using a three-way analysis of variance.

Table l. Effect of Dietary Vanadium and Iodine on Plasma T_3 and T_4, Serum Lactate Dehydrogenase (SLD), and Pancreatic Amylase (PA) in Diabetes-Prone (PR) and -Resistant (R) BB/Wor Rats

Dietary[a]		Rat	Plasma T_4	Plasma T_3	PA	SLD
V, µg/g	I, µg/g	Type	µg/100 mL	ng/100 mL	U/mg protein	U/L
0.0	0	PR	5.06 ± 0.98[b]	27.4 ± 7.4	114 ± 14	964 ± 100
0.5	0	PR	2.81 ± 0.23	35.1 ± 2.9	102 ± 12	910 ± 101
0.0	0	R	4.78 ± 0.45	31.3 ± 7.9	119 ± 12	1060 ± 92
0.5	0	R	2.93 ± 0.43	41.5 ± 6.9	74 ± 7	902 ± 174
0.0	25	PR	5.05 ± 0.49	33.1 ± 8.7	114 ± 15	924 ± 119
0.5	25	PR	5.65 ± 0.55	32.4 ± 7.7	81 ± 12	977 ± 110
0.0	25	R	5.61 ± 0.40	36.5 ± 6.7	105 ± 8	927 ± 154
0.5	25	R	5.79 ± 0.36	34.4 ± 7.1	78 ± 11	1106 ± 169

[a] Amount of V and I supplemented to diet. [b] mean ± SD
Significant effects - T_4: V, P<0.0001; I, P<0.0001; V x I, P<0.0001. T_3: V x I, P<0.008, Rat type. P<0.04. PA: V, P<0.0001; I, P<0.02; Rat type, P<0.008; V x Rat type, P<0.04; V x I x Rat type, P<0.004. SLD: V x I, P<0.004

As shown in Table 1, when the rats were fed the low I diet, T_4 concentrations were much less in V-supplemented than -deprived rats. Increasing dietary I markedly increased the T_4 concentrations in the V-supplemented rats but had very little effect on the concentrations in the V-deprived rats. When dietary I was low, the plasma T_3 was higher in V-supplemented than -deprived rats. Iodine supplementation decreased the T_3 concentration in V-supplemented rats, but increased it in the V-deprived rats. The activity of PA, which catalyzes the first step in the digestion of dietary starch to glucose, was lower in V-supplemented than -deprived rats. This difference was much greater in the diabetes-resistant than diabetes-prone rat when dietary I was low. An interaction between I and V also affected the activity of SLD, the last enzyme in the glycolysis pathway. These findings support the contention that V has a biochemical role that affects thyroid and carbohydrate metabolism in higher animals.

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INTERRELATION BETWEEN ZINC AND IRON NUTRITURE IN RATS

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Numerous physiological functions of zinc (Zn), copper (Cu) and iron (Fe) have been reported (1). Various experiments have shown that these metals should be presented in food in a proper balance for optimal health and biological function. Moreover, it is known that because of the interactions between Zn and Cu and between Cu and Fe, these elements should not be considered as independent nutrients when the optimal supply of these elements is sought. A more biologically meaningful approach should take into consideration functional dependencies among Zn, Cu and Fe. Several reports have established antagonistic relationships between Zn and Cu and between Cu and Fe (2,3). At the same time, little has been reported about the interaction between Fe and Zn. Our research has been designed to fill this gap and to provide information that can be used in mathematical modeling of functional relationships among Zn, Cu and Fe.

A 5 x 4 factorially arranged experiment was used with groups of six Sprague-Dawley weanling male rats fed AIN 93-based diets. Dietary variables were Fe at 4, 12, 24, 48 or 96 μg/g diet and Zn at 5, 10, 20 or 40 μg/g diet. Body weight was measured once per week and food consumption 5 days per week. After 7 weeks, liver, heart, spleen and kidneys were collected, weighed, and stored for trace element analysis (Ca, Cu, Fe, K, Mg, Mn, Mo, P, and Zn). We also measured 16 characteristics of blood as well as plasma trace elements, ceruloplasmin and cholesterol. Nonlinear models such as saturation curves and fractional power were used to fit the experimental data (as related to least square deviations) and reveal previously unreported patterns.

In this report we summarize some preliminary results. For dietary Zn >10 μg/g, liver weight increased with increasing Fe (>12 μg/g). These data can be modeled by using a saturation curve when Fe approaches 96 μg/g. The response of the liver weight to Zn variations is almost negligible in this interval. We found a moderate increase in the heart weight that follows the increase of Zn from 5 to 10 μg/g when Fe was between 12 and 96 μg/g. The response to changes in dietary Zn depended on the amount of dietary Fe; the more Fe in the food, the more marked the increase in the heart weight with increasing Zn. Therefore, we suggest a weak positive feedback control of Zn by Fe. For Fe >12 μg/g and Zn >10 μg/g the kidney weight increases with increasing Fe; these data can be modeled by a saturation curve when dietary Fe approaches 96 μg/g. The kidney weight is almost insensitive to changes in dietary Zn in this interval. For Fe >12 μg/g and Zn >10 μg/g, the spleen weight is independent of Fe and Zn.

The blood response is summarized in Table 1. We consider two subintervals for Zn: [5-10 μg/g] and [10-40 μg/g] and three subintervals for Fe: [4-12 μg/g], [12-48 μg/g] and [48-96 μg/g]. The nomenclature "-/+/0" stands for "decrease/increase/neutral" of the corresponding parameter within the specific interval.

TABLE 1. Blood Response to Independent Variations in Dietary Fe and Zn

	Zn, μg/g		Fe, μg/g		
Parameter	**5-10**	**10-40**	**4-12**	**12-48**	**48-96**
BASOPHILS	0	0	+	0	-
EOSINOPHILS	+	0	+	0	+
HEMATOCRIT	0	0	+	0	0
HEMOGLOBIN	0	0	+	0	0
LYMPHOCYTES	0	0	-	0	+
CORPUSCULAR HEMOGLOBIN	0	0	+	0	0
CORPUSCULAR HEMOGLOBIN CONCENTRATION	0	0	+	0	0
MEAN CORPUSCULAR VOLUME	0	0	+	0	0
MONOCYTES	+	+	-	0	+
MEAN PLATELET VOLUME	-	0	+	-	0
NEUTROPHILS	+	-	-	0	+
PLATELET DISTRIBUTION WIDTH	-	0	+	-	0
PLATLETS	0	-	-	-	0
RED BLOOD CELLS	0	0	+	0	-
RED CELL DISTRIBUTION WIDTH	-	0	-	-	-

The main conclusion is that a strong interaction between Fe and Zn occurs with dietary concentrations of Zn between 5 and 10 μg/g and with Fe > 12 μg/g. Dietary Zn < 10 μg/g and Fe between 4 and 12 μg/g were not covered sufficiently in this experiment and is in need of further investigation.

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ASSIGNING DATES TO LAKE AGASSIZ STRANDLINES WITH A POST-GLACIAL REBOUND CURVE

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During the Wisconsinan glaciation eastern North Dakota and northwestern Minnesota were depressed by the weight of the Des Moines Lobe ice. Glacial Lake Agassiz formed in this depression following retreat of the ice, and left strandlines along the lake margins. These strandlines have been tilted by differential post-glacial rebound (1). The viscosity of the asthenosphere controls post-glacial rebound rates (2), and the asthenosphere viscosity here has been calculated as 6.5×10^{22} Pa sec (3). This viscosity is then used, along with the age of the Herman strandline (10,900 C^{14} years B.P., used as a base level), to construct a post-glacial rebound curve for the Lake Agassiz basin. The ages of other strandlines in the basin are then determined from that rebound curve.

The dates assigned to the strandlines using the rebound curve are shown in Table 1 together with the dates that are currently accepted. The rebound curve dates for the Norcross, Gladstone, and Burnside strandlines do not agree well with currently accepted dates. The Tintah date shows fair agreement with currently accepted dates, and the Campbell strandline date shows good agreement with currently accepted dates. The McCauleyville through Ojata strandlines show very good agreement to the currently accepted dates (within 100 years in each case). Using the currently accepted dates, it would appear that Lake Agassiz formed a new strandline every 100 years starting with the McCauleyville. We propose that the pattern of alternating between stable periods and periods of rapid strandline formation, as is indicated by the rebound curve, is more likely in the case of a natural system such as Lake Agassiz.

The rebound curve constructed for the study assumes the errors in C^{14} dating of the strandlines are averaged out by the rebound curve. Improving the dates acquired with the rebound curve would require new C^{14} dates on at least two widely spaced strandlines that could clearly be shown to be more accurate than the C^{14} dates currently used. Another improvement would be determination of mantle viscosity using a method independent of the strandlines, namely some form of geophysical remote sensing. Barring such a breakthrough, we believe that the post-glacial rebound curve offers more accurate dates for formation of the Lake Agassiz strandlines and provides valuable information concerning the amount of time elapsed between the formation of individual strandlines.

Table 1 – Strandline dates as determined by the post-glacial rebound curve versus currently accepted dates.

Strandline	Curve Date	Current Date	Difference§
Herman	10,900	10,900	0
Norcross	10,500	9,900	600
Tintah	10,150	9,800	350
Campbell	9,600	9,400	200
McCauleyville	9,100	9,100	0
Blanchard	8,950	9,000	-50
Hillsboro	8,950	8,900	50
Emerado	8,800	8,800	0
Ojata	8,600	8,700	-100
Gladstone	8,000	8,600	-600
Burnside	8,000	8,500	-500

All ages are given in years B.P.
* - Currently accepted dates are compiled from 4, 5, 6.
§ - Difference in years between the curve date and the current date, calculated as curve date - current year. Positive values indicate the curve date is older than the current date, negative values indicate the curve date is younger.

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2. Turcotte, D. L., and Schubert, G. (1982) Geodynamics: John Wiley and Sons, New York, 450 pp.
3. Brevik, E. C., and Gosnold, W. D. (1998) Asthenosphere Viscosity..., Proceedings NDAS 52, 46.
4. Teller, J. T. (1997) written communication.
5. Thorleifson, L. H. (1996) *in* J. T. Teller, L. H. Thorleifson, G. Matile, and W. C. Brisbix, eds, Sedimentology, Geomorphology, and History of the Central Lake Agassiz Basin, pp 55-84.
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ASTHENOSPHERE VISCOSITY BENEATH THE SOUTHERN LAKE AGASSIZ BASIN

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Asthenosphere viscosity beneath the Lake Agassiz basin was calculated from post-glacial rebound rates using the relationship $F(k, t) = F_0(k)e^{-t\alpha(k)/Tr}$, where F(k, t) is depression as a function of k (the wavenumber) at time t, $F_0(k)$ is initial depression, t is elapsed time since rebound began, α is the "lithospheric filter", and Tr is the asthenosphere relaxation time (1). For the Lake Agassiz basin, α = 205 km (2).

Asthenosphere relaxation time is given by $Tr = (4\pi v)/(\rho_m gl)$, v is asthenosphere viscosity, ρ_m is asthenosphere density, g is gravitational acceleration, and l is wavelength of the ice sheet (3). Asthenosphere density is 3300 kg/m^3 (1), the wavelength of the Laurentide Ice Sheet was about 3,000 km (4), and g is 9.81 m/s^2 at 49° N. Rebound rates were calculated from the tilt of dated strandlines in the Lake Agassiz basin, and post-glacial rebound curves were constructed for the Lake Agassiz basin using a range of asthenosphere viscosities. The viscosity value that produced the curve that best fit the strandline data was assumed to be accurate. Figure 1 shows the observed strandline rebound (5, 6) versus currently accepted strandline dates (7) compared to three rebound curves generated using assumed viscosities. Figure 2 shows a close-up of the outlined area at the tail end of the curves in Figure 1.

The 6.5 X 10^{22} Pa sec curve provides the best fit to the observed data. This is greater than the values commonly given for asthenosphere viscosity, for example, 1 X 10^{21} Pa sec (8), and up to 1 X 10^{22} Pa sec (9). However, recent studies beneath the Canadian Shield suggest the asthenosphere viscosity there is higher than average (10, 11). Some have concluded there are lateral variations in asthenosphere viscosity, the effective viscosity may range through a full order of magnitude, and the highest values of viscosity are beneath the Canadian Shield (12), which is along the eastern edge of the Lake Agassiz basin. Therefore, we accept 6.5 X 10^{22} Pa sec as the asthenosphere viscosity beneath the Lake Agassiz basin.

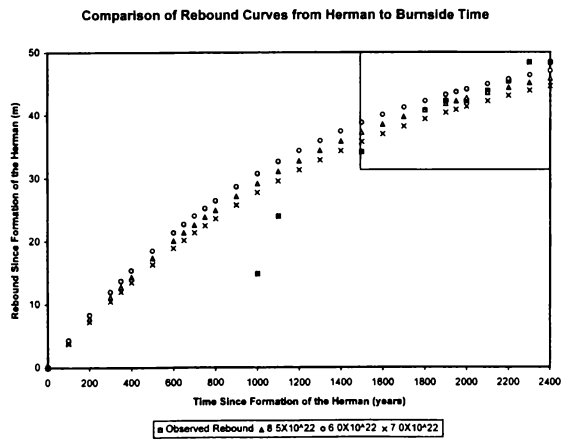

Figure 1 – Comparison of observed to experimental curves.

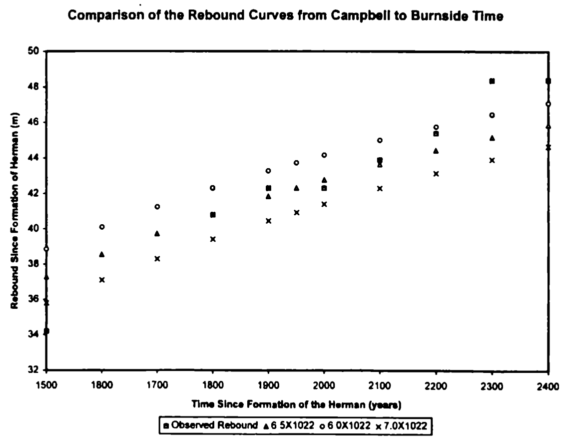

Figure 2 – Close up of the outlined section of Figure 1.

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CONSTITUTION of the NORTH DAKOTA ACADEMY OF SCIENCE

Founded 1908, Official State Academy 1958

ARTICLE I - *Name and Purpose*

Section 1. This association shall be called the NORTH DAKOTA ACADEMY OF SCIENCE.

Section 2. The purpose of this association shall be to promote and conduct scientific research and to diffuse scientific knowledge.

ARTICLE II - *Membership*

Membership in the Academy shall be composed of persons who share the stated purpose of the Academy and who are active or interested in some field of scientific endeavor.

ARTICLE III - *Council*

The officers of the Academy shall be a President, a President-Elect, and a Secretary-Treasurer. The Council, consisting of the officers, the retiring President, and three elected Councilors, shall be responsible for the fulfillment of the scientific and business obligations of the Academy.

ARTICLE V - *Dissolution and Limits of Action*

Section 1. In the event of dissolution of the Academy, any remaining assets shall be distributed to organizations organized and operated exclusively for education and scientific purposes as shall at the time qualify as exempt organizations under Section 501(c) (3) of the Internal Revenue Code of 1954.

Section 2. No substantial part of the activities of the Academy 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.

Section 3. No part of any net earnings shall inure to the benefit of, or be distributable to, Academy members or officers, or other private persons, except that the Academy may authorize the payment of reasonable compensation for services rendered.

ARTICLE VI - *Amendments*

Section 1. This Constitution may be amended at any annual Business Meeting of the Academy by a two-thirds vote. Proposed amendments shall be submitted in writing to the Secretary -Treasurer who shall send them to the members at least two weeks before the meeting at which such amendments are to be considered.

Section 2. Bylaws may be adopted or repealed at any regular business meeting by a two-thirds vote.

BYLAWS

BYLAW 1. *Meetings*

Section 1. *Scientific Meetings.* The Academy shall hold at least one annual scientific meeting each year at a time and place determined by the Council. Other scientific meetings, regional, state, or local, may be held at times and places determined by the Council. The Council shall establish regulations governing the presentation of papers at Academy sessions. Such regulations shall be made available to members at least three months before any meeting at which they are to apply.

Section 2. *Business Meetings.* A Business Meeting of the membership shall be scheduled at the regular, annual scientific meeting of the Academy. Ten percent of the active members shall constitute a quorum at the annual business meeting.

Section 3. *Special Meetings.* Special meetings shall be called by the President upon the request of ten percent of the active members and require twenty percent of the active members for a quorum. Notice of the time and place of such meetings shall be sent to all members of the Academy at least four weeks in advance of the meeting. Only matters specified in the call can be transacted at a special meeting.

Section 4. *Procedure.* Parliamentary procedures to be followed in all business meetings shall be those specified in "Standard Code of Parliamentary Procedure" by Alice F. Sturgis.

BYLAW 2. *Financial*

Section 1. *Dues and Assessments.* The annual dues and assessments may be changed from time to time by the Council, subject to approval by a two-thirds vote of the members at an annual Business Meeting. The student member dues shall be one-third (to nearest dollar) of the regular member dues. These dues are payable 1 December of each year.

Section 2. *Supporting Members.* Council shall maintain a program to encourage members to voluntarily contribute funds over and above the regular dues and assessments for the support of activities of the Society.

Section 3. *Sustaining Members.* Any association, corporation, institution, or individual desiring to support the Society with funds or services valued at $50 or greater may be invited by the President or designee to become a Sustaining Associate.

Section 4. *Audit and Reports.* The Nominating Committee shall appoint on a yearly basis one member who is not a member of Council to conduct at least one internal audit per year. The Secretary-Treasurer shall report on the financial affairs of the Society, including the results of an annual audit, as may be requested by the Council.

BYLAW 3. *Membership*

Section 1. *Membership Categories.* Classes of membership shall include the following: (a) Regular, (b) Student, (c) Emeritus, (d) Honorary, (e) Supporting, (f) Sustaining, and (g) Lifetime Members.

Section 2. *Eligibility and Procedure for Membership.* Candidates for membership, except Sustaining Member, may be proposed by any regular or emeritus member of the Academy by submitting the candidate's name to the chairman of the Membership Committee.

(a) *Regular Members.* Any person who is active or interested in some field of scientific endeavor shall be eligible for regular membership. A majority vote of Council shall elect to regular membership.

(b) *Student Members.* Any student who is an undergraduate or graduate student in some field of science shall be eligible for student membership. A majority vote of Council shall elect to regular membership.

(c) *Emeritus Members.* Any member in good standing upon formal retirement is eligible for emeritus membership. A majority vote of Council shall elect to emeritus membership.

(d) *Honorary Members.* 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 Academy to honor in this fashion. A two-thirds vote of members attending the annual business meeting shall elect to honorary membership.

(e) *Supporting Members.* Regular or student members may voluntarily contribute funds over and above the regular dues and assessments for the support of activities of the Society.

(f) *Sustaining Associates.* Any association, corporation, institution, or individual desiring to support the Society with funds or services valued at $50 or greater may be invited by the President or designee to become a Sustaining Associate.

(g) *Lifetime Members.* Any regular member in current good standing for at least one year may become a Lifetime Member by paying an assessment equal to 18 times the current annual dues in one lump sum or in two equal payments over the current and following year.

Section 3. *Privileges of Membership.*

(a) Voting at the annual business meeting is permitted of regular and emeritus members.

(b) Members of all categories may attend business meetings of the Academy.

(c) The Secretary-Treasurer and members of Council must be regular members in good standing.

(d) Regular, student, and emeritus members may submit abstracts or communications for scientific meetings of the Academy.

(e) Emeritus and Honorary Members shall be exempt from payment of dues.

(f) A Sustaining Member is provided a display area at the annual scientific meeting of five linear feet per $50 donation up to a maximum of 20 linear feet.

(g) Every member in good standing shall receive a printed copy or an electronic copy (if available and of equal or lesser cost than the printed copy) of the annual *Proceedings of the North Dakota Academy of Science*, the form to be determined by the member.

(h) Special offices such as Historian may be created by the unanimous vote of the regular members at the annual Business Meeting.

(i) All student research participants shall receive a properly inscribed certificate.

Section 4. *Forfeiture of Membership.*

(a) *Nonpayment of dues.* Members shall be dropped from the active list on 31 November following the nonpayment of dues during the membership year commencing the previous 1 December. A member may return to the active list by paying the current year dues.

(b) *Expulsion for Cause.* Membership may be terminated for conduct injurious to the Academy or contrary to the best interests of the Academy. The accused member shall be given an opportunity for a hearing before the Council. If a majority of the Council votes to expel the member, the action must be ratified by at least two-thirds of the members present at the next annual business meeting of the Academy. An expelled member shall forfeit all paid dues and assessments.

BYLAW 4. *Duties and Responsibilities of the Council and Council Members*

Section 1. *Council.* The Council shall meet, at the call of the President, at least twice a year. The Council shall:

(a) be the governing board of the Academy, responsible only to the membership.

(b) arrange for programs, approve committee appointments, be responsible for the fiscal affairs of the Academy, an transact such business as necessary and desirable for function and growth of the Academy.

(c) determine the location of the annual meeting three years in advance.

(d) 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.

(e) shall appoint and may compensate a Secretary-Treasurer.

(f) shall appoint and may compensate an Editor of the PROCEEDINGS and other publications.

(g) shall be empowered to charge a publication fee of authors on a per page basis.

(h) shall control all activities of the Academy including grant applications.

Section 2. *President.* The President shall preside at meetings of the Council and over the annual business meeting of the Academy at the close of the regular term of office. The President shall vote only to break a tie. Unless otherwise specified, the President shall, with the approval of the Council, appoint members to serve on Standing Committees and *ad hoc* Committees, designate the chair of each Committee, and appoint representatives to other organizations. The President serves as Coordinator of the Local Arrangements Committee for the annual meeting that occurs at the end of the President's term.

Section 3. *President-Elect.* The President-elect shall be considered a vice president and shall serve as such in the absence of the President.

Section 4. *Past-President.* The retiring President shall serve as Past-President and chair of the Nominating Committee. The Past President shall serve ex officio on those committees designated by the President and shall serve in the absence of the President and President-elect.

Section 5. *Secretary-Treasurer.* The Secretary-Treasurer shall:

(1) Assist Council in carrying on the functions of the Academy including the receipt and disbursement of funds under the direction of Council.

(2) Manage the Academy Offices under Council's general supervision.

(3) Serve as Managing Editor of the *Proceedings of the North Dakota Academy of Science.*

(4) Prepare a summary of the most recent audit and a report of the Academy's current financial status. This information shall be shared with the membership at the annual business meeting and published in the PROCEEDINGS following the business meeting.

(5) Perform all other duties of the Secretary-Treasurer listed in the Bylaws.

(6) Serve as archivist and be responsible for all official records, archives, and historic material which shall be in reposit with the Secretary-Treasurer.

BYLAW 5. *Appointment, Nomination and Election of Members of Council*

Section 1. *Eligibility for Office.* All candidates for election or appointment to the Council must be regular members in good standing. Nominees for President-elect must be members who reside within easy commuting distance of the site of the annual meeting selected by the Council that occurs when the President-elect serves as President.

Section 2. *Nomination Procedures.* The Nominating Committee shall be responsible for all nominations to elective office, shall determine the eligibility of nominees, shall ascertain that nominees are willing to stand for office, and shall be required to advance to the Secretary-Treasurer at least two names for each open position as needed. Academy members shall have been encouraged to suggest nominees to the committee prior to the Committee submitting its report.

Section 3. *Election Procedures.* Election shall be by secret mail ballot. The Secretary-Treasurer shall prepare a printed ballot that bears all names submitted by the Nominating Committee, that contains a brief biography of each candidate, and that has space for write-in candidates for each office. This ballot is to be mailed to all members no later than 1 November. Each member wishing to vote must return the marked ballot in a sealed signed envelope to the Secretary-Treasurer postmarked not more than thirty days after the ballots were mailed out to members. The President shall appoint tellers who shall count the ballots which have been received by the Secretary-Treasurer and the tellers shall present the results in writing to the President. A plurality of the votes cast shall be necessary to elect and in the case of a tie vote, the President shall cast the deciding vote. The results of the election shall be announced at the annual Business Meeting.

Section 4. *Term of Office.* A President-Elect shall be elected annually by the membership and the following years shall succeed automatically to President and Past President to constitute a three year nonrenewable term. Three Councilors shall be elected by the membership to three-year, non-renewable terms on a rotating basis. All elected Council members shall take office at the end of the next annual Business Meeting following election and shall continue until relieved by their successors. Council is empowered to appoint and compensate a Secretary-Treasurer to successive three-year terms that commence with the beginning of the fiscal year.

Section 5. *Removal from office or position* If for any reason any elected member of Council is unable to fulfill his/her duties, the Council member may be removed from office by two-thirds vote of Council. If for any reason the Secretary-Treasurer is unable to fulfill his/her duties, the Secretary-Treasurer may be relieved of all duties by a majority vote of Council.

Section 6. *Interim vacancies.* Should a vacancy occur in the Presidency, the Council by a majority vote shall appoint a member of the Academy able to coordinate the next annual meeting to fill the unexpired term. A retiring interim President shall succeed automatically to Past President. Should a vacancy occur in the Presidency-elect, the Council shall reassess and change the location of the coinciding annual meeting as necessary and then call for a special election by mail ballot. An interim vacancy in the Past-Presidency shall be filled by the most recently retired Past-President able to fill the duties of the Past-President. Persons appointed to fill the unexpired term of Secretary-Treasurer are expected to remain in the position for a minimum of three years. A vacancy in the office of Councilor shall be filled by a majority vote of Council until the following election at which time the interim Councilor may stand for a full three year nonrenewable term.

BYLAW 6. *Committees*

Section 1. Standing Committees. Standing committees shall include but not be limited to, the following: Editorial, Education, Denison Award, Necrology, Nominating, Resolution, Membership, and Audit Committees. The President shall appoint members of committees other than the Nominating and Audit Committees.

Section 2. *Editorial Committee.* The Editorial Committee shall consist of three regular members appointed to three year terms. The duties are explained in BYLAW 7 (Publications).

Section 3. *Education Committee.* The Education Committee shall consist of five regular members and two high school teachers appointed to five year terms. 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.

Section 4. *Denison Awards Committee.* The Denison Awards Committee shall consist of six regular members appointed to three year terms. 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.

Section 5. *Necrology Committee.* The Necrology Committee shall consist of three regular members appointed to three year terms. The Necrology Committee shall report to the annual meeting on those deceased during the preceding year. Obituaries may be included in the minutes of the annual meeting and/or published in the Proceedings.

Section 6. *Nominating Committee*. The Nominating Committee shall consist of the five most recent past-presidents. The major duties of the Nominating Committee are listed in BYLAW 5 (*Appointment, Nomination and Election of Members of Council*). The Nominating Committee will also administer the selection process, develop a separate funding source for a monetary award, and develop, for Executive Committee approval, the criteria for the North Dakota Academy of Science Achievement Award.

Section 7. *Resolution Committee*. The Resolution Committee shall consist of three regular members appointed to three year terms. The Resolution Committee 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.

Section 8. *Membership Committee*. The Membership Committee shall consist of unlimited numbers of regular members appointed annually.

Section 9. *Audit Committee*. The Nominating Committee shall appoint on a yearly basis one member who is not a member of Council to conduct at least one internal audit per year.

Section 10. *State Science Advisory Committee*. The State Science Advisory Committee (SSAC) shall consist of five regular or emeritus members appointed to four year terms. The SSAC shall serve to direct questions of a scientific nature to the appropriate expert as requested, shall inform regional granting agencies and state and national science policymakers of its expertise and availability and shall counsel those agencies and persons upon their request. The SSAC shall adhere in particular to the guidelines described in Article V, Section 2 of the Constitution.

Section 11. *Ad hoc Committees*. The President may appoint such additional committees as may be needed to carry out the functions of the Academy. Ad hoc committees serve only during the tenure of the president who appointed them. Reports of ad hoc committees shall be presented to Council or to the annual meeting.

BYLAW 7. *Publications*

Section 1. *Editorial Committee*. Three regular members are appointed to the Editorial Committee for renewable three year terms. The Editorial Committee shall develop and recommend the Academy publication program and policies to the Council. It will assist the Editors of each official publication in reviewing manuscripts for those publications that include the *Proceedings*. Chairs of symposia will review manuscripts written for relevant symposia.

Section 2. *Managing Editor*. The Secretary-Treasurer shall serve as the Managing Editor of all Academy publications and as such shall oversee each Editor.

Section 3. *Editor*. Editors shall serve three year terms. The Editors shall edit all official publications of the Academy including the *Proceedings*.

BYLAW 8. *Memorial Fund*

The Council of the Academy shall establish a J. Donald Henderson Memorial Fund and administer this fund so that the proceeds will be used to promote science in North Dakota.

BYLAW 9. *Fiscal Year*

The fiscal year of the North Dakota Academy of Science, for the purpose of financial business, shall be 1 January to 31 December.

BYLAW 10. *Achievement Award*

The Academy establishes the North Dakota Academy of Science Achievement Award to be given periodically to an Academy member in recognition of excellence in one or more of the following:

a. Nationally recognized scientific research.
b. Science education.
c. Service to the Academy 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 Council approval, the criteria for the award.

BYLAW 11. *Research Foundation*

The **North Dakota Science Research Foundation** is established as an operating arm of the Academy. 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 Secretary-Treasurer of the Academy and shall be separately accounted for annually.

The Foundation Board of Directors shall be comprised of five members of the Academy , representing different disciplines. Members shall be appointed by the President of 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 Academy at each annual meeting, and the Secretary-Treasurer shall present an accompanying financial report.

BYLAW 12. *Affiliations*

The Academy may affiliate itself with other organizations which have purposes consistent with the purposes of the Academy. Such affiliations must be approved by the Council and by a majority of those attending a regularly scheduled business meeting of the membership.

BYLAW 13. *Indemnification*

Section 1. Every member of the Council or employee of the North Dakota Academy of Science shall be indemnified by the Academy against all expenses and liabilities, including counsel fees, reasonably incurred or imposed upon him/her in connection with any proceedings to which he or she may be made part, or in which he or she may become involved, by reason of being or having been a member of the Council, or employee at the time such expenses are incurred, except in such cases wherein the member of the Council or employee is adjudged guilty of willful misfeasance or malfeasance in the performance of his or her duties. Provide, however, that in the event of a settlement of the indemnification herein shall apply only when the Council approves such settlement and reimbursement as being for the best interests of the Academy.

The foregoing right of indemnification shall be in addition to and not exclusive of all other rights to which such members of the Council or employee may be entitled.

Approved Minutes of the North Dakota Academy of Science Business Meeting
September 16, 1997
Memorial Union, South Ballroom, University of North Dakota, Grand Forks, ND
12:45 PM

The meeting was called to order by President Hunt. Members of the Executive Committee were recognized. Hunt thanked the members of the Local Arrangements Committee, the organizers of the symposia and the speakers for all the time and effort they put in to make the meeting successful, the Memorial Union for allowing the NDAS to hold our meeting there at no charge, the University of ND for institutional support in the form of $1000, and the Otto Bremer and Bush Foundations for the grant of $5400 to help offset the costs associated with the Devils Lake and Red River Flood Symposia. He mentioned that writing grants for public interest symposia will be done again and reminded us that any grant writing on behalf of the NDAS must be cleared through the Executive Committee. He asked for comments about having posters as an option for presentations at future NDAS meeting. The response was positive. This year we had 9 posters from the Department of Anatomy and Cell Biology - without the option of posters, their papers probably would not have been presented. An effort was made to attract media attention to the meeting - this was successful in that the local television stations and newspaper covered the symposia on Devils Lake and the Red River Flooding. Attendance and interest was heightened because of these two symposia. This was the first attempt at presenting public interest symposia and it was hugely successful - we will carry this on to future meetings.

Meeting statistics:
Attendees: 270
Eight symposia with 48 presentations
Professional papers: 24 oral, 9 poster
Denison undergraduate papers: 5
Denison graduate papers: 11

With the addition of the Red River Flood symposium and addition of several talks in the Astronomy symposium (not reflected in the meeting program), we had more symposia talks than originally scheduled for the April meeting. The flood hurt the Denison presentations the most - originally 33 were scheduled with 16 presented. Of the 44 professional presentations scheduled (this number includes poster presentations) 33 were presented.

State Science Fair:
The NDAS gives two $25 awards at the State Science Fair. This year the winners were: Erin Nyren from Gackle and Robert Jentz from Hankinson.
Concerns about the State Science Fair were noted. Apparently there has been pressure to censor some of the projects. The Executive Committee will try to get further information on this activity and decide whether or not the Academy should provide future awards.

Junior Academy of Science:
The Junior Academy was held separately from the regular meeting because of the flood in Grand Forks and subsequent postponement of the annual meeting. Winners from the senior division of the Junior Academy are invited to present their papers at the Minnesota Academy of Science, which is usually held in October. Holding the Junior Academy at the rescheduled dates of Sept 15-16 would not have given the organizers of the Minnesota Junior Academy enough lead time to accept the NDAS Junior Academy winners. Thus, the meeting was held June 13. The winners in the Senior Division were: first, Kayla Muehler, Hankinson; second, Cortland Barnes, Jamestown; and third, Joshua Pankow, Hankinson. In the Junior Division the winners were: first, Robert Jentz, Hankinson; second, Jeremy Pankow, Hankinson; and third, Elisha Jones, Jamestown. The Academy expresses its appreciation to Dana Metzger (Grand Forks) who was in charge of the Junior Academy this year.

Denison Award:
Winners of the Denison competition were - (graduate division) Winner ($100): James Johnson, UND; Runners up ($50 each): Robert Current, UND; and Deborah Beck, UND. Undergraduate Winner ($100) Scott Tschackofske, UND; Runners up: Darren Huber and Mike Moen (team presentation, $25 each), NDSU; and Petra Fox ($50), UND.

Election Results:
Rich Novy (Fargo) and Eric Hugo (Dickinson) were elected as members-at-large (now called councilors). Joseph Hartman (UND-EERC, Grand Forks) was elected President-elect.

Committee reports:
Necrology Committee (Michael Thompson, chair: Uthus reporting) reported the passing away of one NDAS member, Richard Marwin. A moment of silence was observed in remembrance of Dr. Marwin.

Research Foundation (Uthus reporting):
North Dakota Research Foundation Grant ($500) was awarded to Andre DeLorme, Valley City State University. The money will support the Sheyenne River Invertebrate Assessment Project.

Resolution Committee:
No resolutions brought forward. This committee needs a chair as the current chair has moved out of the state.

Membership Committee:
No news was reported except for a comment by Uthus that President Hunt solicited new members from various science departments on the campuses of UND and NDSU. Allen Kihm, Dan Mott (before leaving), and Eileen Starr made special recruitment efforts at their respective institutions.

Nominating Committee:
The nominating committee has successfully recruited Dr. Allen Kihm (Minot) to run for the vacant position of President because President-elect Mott accepted a new faculty position out of state.

Editorial Committee (Uthus Reporting):
Two issues of volume 51 of the Proceedings were printed this year; the regular issue was printed in April and a supplement containing the Red River Flood Symposium was printed in September. The layout of the Proceedings has changed to give the publication a more professional image. For example the meeting program was deleted. All submissions are now on disk so that a consistent layout can more easily be achieved. Submission of the Proceedings on disk also allows for the possibility of creating electronic versions. These are available as pdf files on the NDAS home page (http://www.gfhnrc.ars.udsa.gov/ndas). These files can be easily searched and pages printed. Future possibilities include an enhanced pdf version (better indexing/searching) or CD-ROM versions.

There was a discussion as when the printed and electronic versions of the Proceedings should first be made available. Several members felt that the Proceedings and electronic version should not be available until the day of the meeting. They felt that delivery at the annual meeting serves as an incentive to draw people to the meetings. In previous years, the Proceedings were not passed out until the meeting to save on mailing costs and copies were mailed out after the meeting to non-attending members. This year, the electronic version was posted to our home page before the printed version was printed but was available only for a short time because the flood knocked out the server. Some copies of the Proceedings were delivered prior to the meeting through intercampus mail (UND) and several to Minot where they were delivered by a member. The Executive Committee would like to hear more feedback on when the printed and electronic versions should be made available.

Old business:
A minor correction was made to the 1996 business meeting minutes.

New business:
The constitution of the NDAS has undergone a major revision. President Hunt has spent considerable time rewriting, updating, and rearranging the constitution. The changes were endorsed by the Executive Committee. A motion was made and seconded to adopt all changes proposed by President Hunt. After limited discussion, the motion was passed with no opposition voiced. After the revision was adopted President Hunt asked for a motion to delete bylaw 3 section 3i (All student research participants shall receive a properly inscribed certificate and be invited to the banquet dinner as the guests of the Academy). Few students participating in the Denison competition attend the banquet. The Executive Committee will decide

on a year-to-year basis whether or not to pay the banquet costs for the students. A motion to adopt the by-law was made, seconded, and passed.

President Hunt provided some background information to support renewal of the State Science Advisory Committee. One of the main purposes of the Committee is to identify symposium topics that have a broad public interest and to find people to organize such symposia.

Secretary-Treasurer Uthus recommended that regular membership dues be increased from $15 to $20 (student dues from $5 to $7). Increased costs and persistent cash flow problems over the past several years have forced the Academy to borrow (7% interest) money from the Research Foundation and from three NDAS members (no interest). The financial report in the current Proceedings indicates that the Academy membership has not grown but general costs (especially for printing the Proceedings) have increased. For example, Proceeding costs for 1995, 1996, and 1997 (not including the supplement) were $2507, $3699, and $4700, respectively. In 1995 and 1996, 500 copies each were printed and very few remain in stock. In 1997, 600 copies were printed in anticipation of increased in demand. The recommended increase in dues will still not cover all projected expenses. The Academy must continue to rely on additional support (Institutional support, possible page charges, grants, etc). A motion was made to increase the professional dues to $20. The motion was seconded and passed. As per bylaw 2 section 1, student dues are therefore $7 and a lifetime membership is $360 (bylaw 3 section 2g).

Meeting adjourned 2:15 PM

Minutes (Unapproved) of the North Dakota Academy of Science Business Meeting
1:00 PM, Best Western International Inn, Minot ND, April 3, 1998

36 members were in attendance.

After an introduction and presentation of a Denison award by President Allen Kihm the first order of business was to approve the minutes from the September 1997 business meeting. The minutes were approved as presented.

A financial report was presented by Secretary-Treasurer Uthus. A copy of that report will be printed in the 1998 Proceedings of the North Dakota Academy of Science. The Academy at present is financially sound. This in part is the result of the Bremer/Bush grant obtained by Curtiss Hunt for the 1997 meeting. The main expense that the Academy has is the printing of the Proceedings. This year the projected cost is $1500. Next year, when the meeting is in Grand Forks the projected cost is $6000. Outside funding will be sought to help underwrite the cost of printing the Proceedings next year. This year, Minot State University has pledged $500 towards the cost of printing the Proceedings. This year, the Proceedings will be published after the meeting. As soon as they are completed, copies will be mailed to all members.

A necrology report was given by Uthus. Two members passed away since the last annual meeting; Dennis Disrud from Minot State University and Theodore Auyong from the University of North Dakota. Their obituaries will be published in the 1998 Proceedings. Members stood in a moment of silence in remembrance of these two members.

Applications for the North Dakota Research Foundation grant have not yet been reviewed. The Research Foundation Committee will get the applications from the Secretary-Treasurer shortly for review.

Meeting statistics: Fifty-two registered attendees, 2 symposia with 4 presentations in each along with moderated discussion periods, 14 professional talks 2 of which were posters, and 1 Denison (undergraduate) presentation.

The Denison award winner was Ched Phillips from Valley City State University. His presentation entitled "Initiation of a long term invertebrate sampling project on the Sheyenne River" was coauthored by Brian Tangen and Andre DeLorme.

The Academy usually presents awards to two State Science Fair winners. This year, Eileen Starr and Om Madhok will select the awardees.

Kim Michelsen (Grand Forks) has been in charge of the Jr. Academy. This year it will be held in Minot in April following the annual meeting. Shiloh Schnabel is the local coordinator form Minot. In the future, the Academy will try arrange the Jr. Acadmey to coincide with the annual meeting as is traditional.

There was discussion on lack of elections this year. The Nominating Committee has had difficulty finding someone to run for President-elect. This person should be from Fargo as that is where the 1999 meeting (when he/she is President) will take place. We also need to fill one vacant councilor position. As soon as nominations have closed, ballots will be sent to all eligible members. The election will be official not less than 30 days after the declared due date of ballots. Our Constitution now provides this mechanism of election. Normally the ballots would be finalized and counted the day of our business meeting at the annual meeting. Results would be announced then).

President Kihm opened the floor for discussion of allowing an open competition for the Denison awards - that is allowing students from schools other than those from North Dakota institutions of higher education to participate. This could only be done if the original Denison endowment allows (or does not prohibit) non-North Dakota students to participate. A motion was made to allow open competition if not prohibited by the Denison endowment. The motion carried without any descending votes. Secretary-Treasurer Uthus will research the Denison endowment to see if there are prohibitions tied to the awards.

A certificate of appreciation was presented to Past-president Hunt. This certificate, which was supposed to have been presented during last year's annual meeting, thanked him for his work as President of the Academy. A certificate of appreciation was then given to Allen Kihm by Curtiss Hunt, thanking Allen for his work as President of the Academy.

Allen Kihm officially ended his duties as President by introducing Joseph Hartman (UND, EERC). President Hartman discussed next year's meeting which will be held in Grand Forks on April 15 and 16, 1999.

Meeting adjourned 1:45 PM

ACADEMY OFFICERS AND COMMITTEES

Executive Committee
Membership:
- Past-President
- President
- President-Elect
- Secretary-Treasurer
- Councilors (three-year terms)

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President-Elect
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Councilor
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Councilor
unfilled

Committees of the North Dakota Academy of Science

Executive Committee

Editorial Committee

Education Committee

Denison Awards Committee

Necrology Committee

Nominating Committee

Resolution Committee

Membership Committee

North Dakota Research Foundation Board of Directors

PAST PRESIDENTS AND LOCATION OF THE ANNUAL MEETING

NORTH DAKOTA ACADEMY of SCIENCE

1909	M A Brannon	Grand Forks	1954	C O Clagett	Fargo
1910	M A Brannon	Fargo	1955	G A Abbott	Grand Forks
1911	C B Waldron	Grand Forks	1956	H B Hart	Jamestown
1912	L B McMullen	Fargo	1957	W E Cornatzer	Grand Forks
1913	Louis VanEs	Grand Forks	1958	W C Whitman	Fargo
1914	A G Leonard	Fargo	1959	Arthur W Koth	Minot
1915	W B Bell	Grand Forks	1960	H J Klosterman	Fargo
1916	Lura Perrine	Fargo	1961	Vera Facey	Grand Forks
1917	A H Taylor	Grand Forks	1962	J F Cassel	Fargo
1918	R C Doneghue	Fargo	1963	C A Wardner	Grand Forks
1919	H E French	Grand Forks	1964	Fred H Sands	Fargo
1920	J W Ince	Fargo	1965	P B Kannowski	Grand Forks
1921	L R Waldron	Grand Forks	1966	Paul C Sandal	Fargo
1922	Daniel Freeman	Fargo	1967	F D Holland, Jr	Grand Forks
1923	Norma Preifer	Grand Forks	1968	W E Dinusson	Fargo
1924	O A Stevens	Fargo	1969	Paul D Leiby	Minot
1925	David R Jenkins	Grand Forks	1970	Roland G Severson	Grand Forks
1926	E S Reynolds	Fargo	1971	Robert L Burgess	Fargo
1927	Karl H Fussler	Grand Forks	1972	John C Thompson	Dickinson
1928	H L Walster	Fargo	1973	John R Reid	Grand Forks
1929	G A Talbert	Grand Forks	1974	Richard L Kiesling	Fargo
1930	R M Dolve	Fargo	1975	Arthur W DaFoe	Valley City
1931	H E Simpson	Grand Forks	1976	Donald R Scoby	Fargo
1932	A D Wheedon	Fargo	1977	Om P Madhok	Minot
1933	G C Wheeler	Grand Forks	1978	James A Stewart	Grand Forks
1934	C I Nelson	Fargo	1979	Jerome M Knoblich	Aberdeen, SD
1935	E A Baird	Grand Forks	1980	Duane O Erickson	Fargo
1936	L R Waldron	Fargo	1981	Robert G Todd	Dickinson
1937	J L Hundley	Grand Forks	1982	Eric N Clausen	Bismarck
1938	P J Olson	Fargo	1983	Virgil I Stenberg	Grand Forks
1939	E D Coon	Grand Forks	1984	Gary Clambey	Fargo
1940	J R Dice	Fargo	1985	Michael Thompson	Minot
1941	F C Foley	Grand Forks	1986	Elliot Shubert	Grand Forks
1942	F W Christensen	Fargo	1987	William Barker	Fargo
1943	Neal Weber	Grand Forks	1988	Bonnie Heidel	Bismarck
1944	E A Helgeson	Fargo	1989	Forrest Nielsen	Grand Forks
1945	W H Moran	Grand Forks	1990	David Davis	Fargo
1946	J A Longwell	Fargo	1991	Clark Markell	Minot
1947	A M Cooley	Grand Forks	1992	John Brauner (elect)	Grand Forks
1948	R H Harris	Fargo	1993	John Brauner	Jamestown
1949	R B Witmer	Grand Forks	1994	Glen Statler	Fargo
1950	R E Dunbar	Fargo	1995	Carolyn Godfread	Bismarck
1951	A K Saiki	Grand Forks	1996	Eileen Starr	Valley City
1952	Glenn Smith	Fargo	1997	Curtiss Hunt	Grand Forks
1953	Wilson Laird	Grand Forks	1998	Allen Kihm	Minot

Financial Statement, 12/31/97

	1995	1996	1997
ASSETS			
Operating Accounts			
Checking	23.89	-424.21	1707.61
Trust Accounts			
Scholarship	23206.92	23700.57	29592.49
Research Foundation	12060.19	13372.85	13573.57
Total	$35,291.00	$36,649.21	$44,873.67
LIABILITIES			
Advanced Dues Payments	78.00		
Restricted Purpose Funds			
Scholarship Principal	23206.92	23700.57	29592.49
Research Foundation	12060.19	13372.85	13573.57
Total	$35,345.11	$37,073.42	$43,166.06
Accumulated Surplus	-54.11	-424.21	1707.61
Change in Surplus		-370.10	2131.82
DUES			
Reinstatements			
Current year	1673.00		1345.00
Future years	78.00		
Sponsor/Patron	599.00		
Total	$2,350.00	$1,069.50	$1,345.00
INSTITUTIONAL SUPPORT			
UND		1000.00	
Valley City State University		250.00	
NDAS Research Foundation	1200.00		
Total	1200.00	1250.00	
ANNUAL MEETING			
Registration fees	1005.00	4148.00	6408.32
Banquet	526.00		
Luncheon			
Sigma Xi - Minot	50.00		
Sigma Xi - UND	50.00		
Bremer/Bush Grant			5400.00
Total	$1,631.00	$4,148.00	$11,808.32
AWARDS PROGRAM			
Scholarship Dividends	829.45	832.20	832.20
NDAS Research Foundation	456.00	500.00	
Total	$1,285.45	$1,332.20	$832.20

	1995	1996	1997
PUBLICATION SALES	112.50		444.50
MISCELLANEOUS INCOME		240.40	
Donations			170.00
Total		$240.40	$170.00
TOTAL INCOME	$6,578.95	$8,040.10	$14,430.02
MEMBERSHIP			
Emeritus	52	58	56
Students	41	53	42
Professional	161	178	141
Delinquent	140	83*	141**
Dropped	88	3	
Other	19		
Total	501	375	380
Member Count	413	289	239
*1995 or before			
**1996 or before			
ANNUAL MEETING			
Speakers Expenses			
Meals/Refreshments	2504.71	1915.55	2511.23
Printing			
General Expenses			
Registration Refund			868.00
Total	$2,504.71	$1,915.55	$3,379.23
AWARD PROGRAMS			
ND Science/Engineering Fair	50.00	50.00	50.00
Denison	400.00	400.00	400.00
ND Junior Academy	350.00	397.50	350.00
Research Foundation Grant	500.00	500.00	500.00
Total	$1,300.00	$1,347.50	$1,300.00
PUBLICATION			
Proceedings	2507.00	3699.00	4820.23
Supplement			1473.73
Total	$2,507.00	$3,699.00	$6,293.96
OFFICE EXPENSES			
Postage	268.74	652.38	965.96
Post Office Box Rental	58.00		39.00

	1995	1996	1997
Duplication	283.21	84.60	635.94
Supplies	63.66		243.73
Clerical Assistance			
Phone	2.96		
Other		501.46	593.73
Bank Fees			24.70
Total	$676.57	$1,238.44	$2,503.06
MISCELLANEOUS			
Fidelity Bond	26.00	26.00	26.00
NAAS Dues	70.00	70.00	64.75
Other	1403.00	23.20	
Research Foundation Loan interest		168.00	238.70
Total	$1,499.00	$287.20	$329.45
Total Disbursements	$8,487.28	$8,487.69	$13,805.70
SCIENCE RESEARCH FOUNDATION			
CASH INCOME			
Donations from Members	212.00	110.00	
Allocations from Dues	244.00	298.00	235.00
Interest Accrued	425.08	1012.50	675.00
Sponsors/Patrons			
Total	$881.08	$1,420.50	$910.00
CASH EXPENSE			
Grants	500.00	500.00	500.00
Interest Compounding	425.08	1012.50	675.00
Other Disbursements	18.00		
Bank Fees			47.52
Total	$943.08	$1,512.50	$1,222.52
Net Change	($ 62.00)	($ 92.00)	($ 312.52)
ASSETS			
Pass Book Savings, 31 Dec	2060.19	3372.85	3573.57
T-Note, book value	10000.00	10000.00	10000.00
Investment Total	$12,060.19	$13,372.85	$13,573.57
Change		$1,312.66	$200.72
SCHOLARSHIP FUND			
CASH INCOME			
ENOVA (SDGE)	426.25	429.00	429.00
IES Industries	403.20	403.20	403.20
Total	$829.45	$832.20	$832.20

		1995	1996	1997
CASH EXPENSE				
Denison Awards		400.00	400.00	400.00
Junior Academy Awards		400.00	375.00	350.00
ND Science and Engineering Fair		50.00	50.00	50.00
Other Expenses			22.50	
TOTAL		$850.00	$847.50	$800.00
Net Change		($ 20.55)	($ 15.30)	$32.20
ASSETS				
ENOVA Shares (1983, 250 shares)		758.86	792.83	836.18
Price	18.50	23.75	22.66	26.94
Value	4625.00	18022.92	17965.53	22524.49
IES Industries (1990, 120 shares)		192	192	192
Price	31.63	27.00	29.87	36.81
Value	3795.60	5184.00	5735.04	7068.00
Total Investment Value		$23,206.92	$23,700.57	$29,592.49
Change			$493.64	$5,891.92

Dennis Disrud

Dr. Disrud was born February 23, 1937, in Rolla. He received his bachelor of arts degree in biology from Concordia College, Moorhead, MN, in 1959 and his master's degree in zoology from Kansas State University in 1961. He received his doctorate degree in plant ecology from North Dakota State University in 1969. Dr. Disrud joined the biology department at Minot State University in 1968. He was recognized for his expertise in North Dakota plants, animals, and geology. He died November 25, 1997, at the age of 60.

Theodore "Ted" Auyong

Dr. Auyong was 72 at the time of his death. He was born January 18, 1925, in Honolulu. In 1954, Auyong received a bachelor's degree in pharmacy and a master's degree in pharmacology a year later from the University of Missouri in Kansas City. He received a doctorate in pharmacology in 1962 from the University of Missouri in Columbia. The following year, Auyong joined the University of North Dakota School of Medicine as an assistant professor. In 1976, Dr. Auyong received the prestigious Golden Apple Award from the American Medical Student Association for outstanding teaching and also served as acting chairman of pharmacology and toxicology from 1986 to 1987. He died January 16, 1998.

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