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MAKING INFORMED DECISIONS FOR GENETIC ENGINEERING: QUESTIONS OF POLICY AND ETHICS

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ABSTRACT—Discussions of molecular biochemistry and genetic engineering frequently evolve into discussions of policy and ethics. Conflicting points of view are often based on whether the technology is perceived as good or evil. In this manuscript, we consider several ethical and policy questions surrounding the scientific advancements in genetic engineering. Those interested in biotechnology are encouraged to recognize the perceptions and motives that influence decisions about genetic manipulations. Expectations for developments in genetic engineering, the regulation of its use, and several policy and ethical considerations are discussed.

Key Words: genetic engineering, biotechnology, ethics, education

INTRODUCTION

Genetic engineering involves changes at the genetic level used to construct or manipulate the products of living systems for new or improved uses and technologies. We, as individuals involved with these techniques, wish to encourage interest and discussions about the ethical aspects of this science and the criteria for making informed decisions.

Ethics, as defined by the *Random House Dictionary*, deals with "values relating to human conduct, with respect to the rightness and wrongness of certain actions and to the goodness and badness of the motives and ends of such actions." Evaluations of the conduct and motives of those using genetic engineering, or any other technique, requires information. Johnson and Thompson (1991) suggest that two types of information are required for informed discussions and suggest one should recognize these types as separate. The first type of information pertains to perceptions of whether an act is good, indifferent, or evil. A standard has been suggested by Immanuel Kant (1909): An act is good when, if performed, the world is a better place; indifferent, if the world would be the same; and evil, if the world would be worse. The second type of information has no relevance to the judgement of whether the act is good or bad, but pertains to the mechanistic process by which an event occurs. For instance, if the gene for growth hormone is put into a rainbow trout, and gives this fish the ability to grow faster and survive better, the information that determines if that was a good or bad event is of the first type. Alternatively, information of the mechanistic processes of identifying, isolating or moving the gene for growth hormone are neither good or evil, and is of the second type of information. A more dramatic example may involve the atom bomb. Information about the process of splitting the atom has no relevance to the judgement of whether making the bomb is good or bad. Evaluating the ***use*** of that process reflects one's perception of good and evil. This categorization of information type may not be universally accepted, but is a valid thought for consideration as information and understanding about genetic engineering are obtained.

So that everyone has a base level of understanding, some information on DNA technology will be presented. Three necessary ingredients for genetic engineering will be discussed here: DNA, living bacterial cells, and restriction enzymes. Imagine rubbing a piece of sandpaper lightly over your arm. The sandpaper would collect hundreds or thousands of cells. Now imagine a single cell as if it were a large paper bag. Peering inside, would reveal a very complex organization of structure. Most obvious, perhaps, would be a nucleus that contains the chromosomes. These structures contain the genetic material that is deoxyribonucleic acid (DNA). DNA molecules are comprised of two long strands of nucleotides. If we imagine each nucleotide as a ball, one cell would contain over 3 billion balls, strung together. If the DNA strands, from one normal sized cell, were stretched out in a straight line, they would be about one meter long.

Four types of nucleotides are used to make DNA. The sequence arrangement of the four nucleotides encodes the genetic information of the cell. The genes are used to produce all proteins, some of which are structural molecules and others are enzymes. Cells are comprised of structural molecules and enzymes that control the chemical reactions. Thus, genes and their products (proteins) are physically part of all tissue, and they direct cell growth, function. and repair. The genetic information to produce proteins which is contained in these genes is passed to successive generations.

In addition to genetic material, DNA technology requires living cells. Living cells have the machinery to chemically "read" the information encoded in the DNA sequence and make the appropriate proteins. When a gene is engineered into a living cell, the cell becomes a factory making the protein specified by the gene. Living bacteria are the most often used cells for DNA technology. Unlike our cells, bacterial cells do not have a nucleus; their one chromosome floats freely in the cell cytoplasm. Also, in addition to their chromosome, bacteria contain significantly smaller pieces of DNA called plasmids. When bacteria divide, the plasmids are copied and they are inherited by the progeny. Compared to the bacterial chromosome, that can contain more that 4000 genes, very little genetic information is contained on plasmids, typically fewer than 10 genes. Because plasmids are small, they can be easily manipulated and are readily passed between bacterial strains. Plasmids have become the "workhorses" in the techniques of DNA manipulation because new genes can be easily added to the plasmids and the newly formed (recombinant) plasmids can be easily placed into recipient bacteria.

Isolating a gene for cloning into a plasmid requires chemically "cutting" the gene from a long sequence of DNA. All cells contain proteins called restriction enzymes, which act as biological knives, capable of cutting DNA at specific locations. The discovery and isolation of specific restriction enzymes has allowed scientists to cut out a gene from a chromosome, cut open a bacterial plasmid, and add the new gene. This gene shuffling results in a recombinant organism capable of synthesizing a new product encoded by the new gene. These basic techniques and their modifications are being used to manipulate the genomes of microorganisms, plants and animals, including man.

Do We Perceive a Problem?

So, what is all the fuss and concern about DNA manipulation and recombinant organisms? Consider the results from three genetic engineering experiments:

1. Until recently, blood was extracted from cows and other large animals, and insulin was isolated from the animal blood for use by diabetic patients. A number of diabetics develop allergic responses to contaminating bovine antigens in the insulin preparations. Genentech, Inc. cloned the human insulin gene into bacteria so that bacteria made human insulin and Eli Lilly Pharmaceutical Corporation acquired from Genentech, Inc., the genetically engineered bacterial strains that produce insulin. They purified the insulin from the bacterial cultures, providing a virtually unlimited supply of pure human

insulin, which may dramatically reduce the cost to patients. The use of human insulin, even when made in bacteria, causes fewer complications than animal-derived insulin.

2. Years ago chemists synthesized new long-lasting pesticides. They were so successful that the new compounds were not degradable by natural processes. Unfortnately, the chemicals have stayed in the environment, unaltered, for decades. Recently, the genes for enzymes that are able to degrade some of these chemicals have been engineered into bacteria. The resulting recombinant organisms can now digest several residual pesticides that have become hazardous waste.

3. Insects have always created problems for farmers by eating crops. As a possible biological insecticide, scientists have been studying an insect virus (baculovirus) that infects and kills insects. A major problem with this approach to insect control has been that the virus takes approximately four days to kill the insects. During the four-day incubation period, the insects continue to eat the crops. To remedy the problem, the gene for a neurotoxin was cloned into the baculovirus. When the recombinant virus infects the insects, the neurotoxin is made and quickly causes insect paralysis so that simultaneous with infection the insects are prevented from eating the crops. As before, the insects die from the virus four days later.

These three examples all appear to be good and lofty genetic engineering endeavors. Why do we have a concern for the results of genetic engineering? Perhaps because it is difficult to get agreement on four very broad questions: 1. Can we be sure that the new creations of biotechnology will not inadvertently upset a balance in nature? 2. Should there be control over "greed versus need" of genetically engineered products? 3. Is our scientific peer-review evaluation system being lost because of the biotechnology revolution? 4. Can there be controlled use of genetic engineering? The following is an examination of each of these questions.

The Balance Of Nature

A familiar historical example of imbalance involved the introduction of rabbits into Australia. Without natural predators, the rabbit population grew without control and resulted in extensive crop damage. Can we be sure that the new creations of biotechnology will not inadvertently upset some balance of nature? What happens if birds eat the insects infected with the neurotoxin-containing baculovirus? What happens if the new enzyme systems in the bacteria engineered to break down wastes are capable of breaking down rubber or plastic? Can we, or will we, identify situations where upsetting the balance of nature is acceptable or unacceptable?

"Greed Versus Need"

Should there be control over "greed versus need"? Recently, an American manufacturer distributed its baby formula in developing countries to new mothers, without charge, for a period of two weeks. If the new mother stopped nursing to use the free formula, the two-week period was just long enough to terminate her lactation. The baby's need for milk didn't change, but now the mother needed to purchase all further supplies of baby formula. Will similar scenarios result from advancements made with biotechnology? A case-in-point is erythropoietin (EPO). This recombinant protein stimulates bone marrow to make red blood cells. It is often given to dialysis patients whose red blood cell counts become very low after long-term dialysis. But, EPO may be used for another purpose that has nothing to do with saving lives. EPO injections will increase red blood cell numbers above the normal levels and provide greater oxygen carrying capacity to the blood. Star athletes, who often have financial resources beyond those of the average dialysis patient, may be able to pay more for EPO to improve their performance. Who then will get the EPO? With only compassionate motives in mind, the Carter Center (Jimmy Carter's world help organization) has arranged for the major producer of EPO to donate 335,000 vials of EPO to dialysis patients in China (Carter, 1991). What will happen when those free vials are gone? Tissue plasminogen activator provides another example. This compound, known to aid victims of heart attack, can only be produced efficiently by recombinant DNA techniques. It costs approximately $2,000 per injection. Is it to be given only to those heart attack victims who have the resources to pay?

These examples illustrate that some products of genetic manipulation have moved from the research bench to the commercial marketplace. Once in the free market are these destined to share the questionable marketing practices of many exploited products?

The Dissemination of Scientific Information

In the midst of the biotechnology revolution, are we losing track of our peer evaluation system and the appropriate means of information dissemination? In the rush to produce new and lucrative products (particularly high value pharmaceuticals), are companies withholding information to insure their monopoly on a product? Recently, a company announced it had discovered a vaccine against a form of Herpes virus. Their research was not published in the usual peer-reviewed scientific journals, it was announced at a news conference. The company had kept their data on the Herpes vaccine a secret from the scientific community. This behavior short circuits the established methods of information dissemination and scientific critique that, in the past, has always checked reported work.

Is the Use of Biotechnology Controlled?

Can there be control over the use of genetic engineering? The "genie" that is biotechnology is "out of the bottle" and can not and will not be put back. The techniques for genetic manipulation and biotechnology are available to every country. Currently, the role (and control) of this technology is still in a process of evolution, influenced by input from all sectors of the population. What types of regulation exist and who determines what regulations are established? Can society trust the scientists and/or companies that develop these techniques to regulate their use?

Scientists have a very respectable record in recombinant DNA research. During the mid 1970s, when the techniques were available to do recombinant DNA work, but the controls for safety and containment of the recombinant microorganisms were not in place, scientists met at their own initiative and imposed a voluntary moratorium on recombinant DNA research for several years. During the moratorium they developed strains of bacteria to be used for recombinant work that can not survive outside of the laboratory. They also instituted the formation of a number of appropriate regulatory agencies.

At many universities across the country, a Biohazard Committee is appointed. At the University of Idaho, this group consists of four faculty members familiar with DNA research, one faculty member from the College of Law, a physician, a laboratory technical staff employee, two individuals from the community, an industrial hygiene specialist, and the University Safety Officer. This committee monitors recombinant DNA experimentation on the campus and acts as a liaison between the UI campus and the federal and state regulatory agencies.

Both state and governmental agencies oversee biotechnology on university campuses and in industry. The Federal Government, with help from the Recombinant DNA Advisory Committee (RAC), issues the "Federal Register" which contains guidelines for all recombinant work. Large conferences are sponsored by both the government and private industry to bring together people doing this work to exchange information and address safety issues. Congress holds numerous hearings with experts and detractors (including views considered by many as radically anti-genetic engineering, e.g., Jeremy Rifkin (1987a, 1987b)) to hear divergent opinions.

Even if we establish elaborate regulations, the human animal is a very unpredictable species. Despite existing regulations, in the spring of 1985, a small biotechnology company, Advanced Genetics Systems, field-tested a genetically altered bacteria (for frost protection of plants) without approval from the Environmental Protection Agency (Baltimore, 1987). Shortly thereafter, the US Department of Agriculture approved testing for another genetically altered product, a viral vaccine for livestock, without consulting its own Recombinant DNA committee (Baltimore, 1987). These two incidents generated a public outcry and sensitized much of the world to a number of concerns about biotechnology.

Questions of Policy and Ethics

Since genetic engineering is here to stay, what kinds of questions should we be asking in order to generate fruitful discussions on the use and morality of this work? One important and fundamental question is: Can recombinant organisms do things we can't predict? Do we have a moral responsibility to worry about it? For example, during the 1920s and 1930s chemists and engineers worked to develop efficient coal burning power plants. An unpredicted result of coal-fired power facilities has been acid-rain. In the 1940s and 1950s scientists worked on preventing nuclear reactor accidents and exposure to high-level radiation without knowledge of the hazards of low level radiation. Every major technological advance tends to create its own "fallout". While regulatory committees can recognize poorly planned work, they can not be expected to see the future. The Federal Government has set guidelines mandating what requirements and containment must be followed for different types of cloning experiments. Initially, only strains of bacteria that cannot survive outside of a laboratory were used in recombinant work. Now, these requirements are being relaxed and approval has been granted for deliberate release of recombinant organisms into the environment. However, the deliberate release of recombinants that will survive in nature still requires the evaluation by, and consent of, several regulatory bodies. But who will take (or be given) the responsibility to watch for unforseen problems or evaluate the potential benefits versus the potential damage?

Are we threatening certain natural resources and genetic diversity? Are we making the world a better or worse place? Genetic engineering has the potential to develop disease-resistant plants. Imagine developing a variety of wheat that is resistant to all known diseases. Farmers would, undoubtedly, resist growing other strains, because the new one would be so much healthier. If, at some future time, a new disease arises that kills this strain of wheat, we may have created a disaster in terms of the world's food supply. We could conceivably lose the genetic diversity that might have allowed some wheat plants to survive the new disease. Similarly, are we threatening aesthetic and cultural values or habitats? Efforts are currently underway to make salt-resistant and drought-resistant crops that could be grown by the sea or in arid land. Profits from these crops may cause the displacement of existing cultures or utilization of now open space and natural habitats for agricultural production. When discussing these issues, it is important to remember that many similar results are obtainable through conventional selective breeding techniques. A major difference between conventional techniques and biotechnology is in the time required to attain potentially tremendous genetic change.

Do genetic manipulations promise improvements for society? The technology which allows us to change or engineer bacteria, plants and animals, will also allow us to change or engineer humans. While the potential for benefit is enormous, the potential for abuse is also present. Many people are concerned that "we are playing God". For some, the manipulation of living things is inseparable from religious doctrine. Biotechnology is sometimes viewed differently from other social and medical advancements because new life systems can be created. Biotechnology doesn't create life from non-living matter, but it does allow the rapid change of existing life forms. The manipulations of DNA done in the laboratory are modest compared to the evolutionary process, which has been credited with producing humans from single celled organisms. The evolution of man took millions of years. In the lab, selected changes in genetics can be done very rapidly: virtually overnight in some cases. However, if we analyze human progress throughout history, we have always done things to alter the fate of our species. Our creativity in developing advancements that benefit individuals is phenomenal. From eye glasses to antibiotics, from open-heart surgery to methods of food preservation, science has extended the life expectancy of many individuals. The one connecting thread, until biotechnology, has been that every advancement has weakened our gene pool. By this we mean that civilization has endeavored to extend the life-time of millions of individuals who would otherwise have died before their child-bearing years. For example, if someone's eye sight was very poor, under completely natural conditions, they would probably die at a young age because they could not see. With the invention of eye glasses these individuals were able to function as if they had perfect eyesight. They matured and gave birth to children who also could not see well, but were helped with eye glasses. The long-term biological effect is to allow the birth of many people that carry genes for defective conditions. This represents a weakening of the gene pool.

Genetic engineering is the first human creation that has the potential to strengthen our gene pool. The permanent correction of genetic diseases is now conceivable. Even though it is technically possible, there is still a moratorium against doing human "germline" therapy (therapy such that the cure would be passed to a person's offspring). "Somatic" therapy (therapy which can only affect the patient, but can not be passed on) has been approved for research. However, the results of somatic therapy do not strengthen the gene pool.

One step towards successful somatic and germline therapies is the Human Genome Project. This endeavor, which is currently underway, will map and sequence the entire DNA component (over 3 billion nucleotide bases) of the human chromosomes. It will result in a blueprint of every human gene and give scientists the potential to locate and modify those genes. The ramifications of manipulating human genes, that will surely follow their mapping, are quite significant. For example, several laboratories are working to isolate the gene(s) that control senescence in eukaryotic cell cultures. Clearly, their goal is the ability to control aging. Undoubtedly, the number of other equally dramatic advances could potentially result from this enormous project.

On the other hand. three billion dollars of tax payer's money has been committed to the Human Genome Project. One might ask, are we so fascinated with these new abilities that we are using our resources unwisely? Should we be dedicating those tax dollars to other projects? Both sides of this issue continue to be intensely debated (Brown, 1991; Roberts, 1990).

How do we make rational decisions about complex issues? One might consider the following thoughts. Ignorance of the issues breeds fear of the unknown. Sensationalizing the issues leads to unrealistic expectations. Only increased understanding and awareness will increase our ability to make informed decisions. Decisions are ethically questionable if there is insufficient, opinionated, untested, or deliberately altered knowledge. Perhaps the most important principles to consider are to "do no harm" and our obligation to "prevent harm". These goals could override efforts to "do good" since it may be wrong to do something good if at the same time it caused harm.

In evaluating the ideas and the different sides of these issues it is important to ask: What wrong is being done and to whom is it being done? An example is given by Johnson and Thompson (1991) who ask, is murder bad because it harms an individual, or is it bad because God commands "thou shalt not kill." In the first case, the victim is harmed; in the second case, God is harmed. Similarly, with respect to biotechnology, we should ask who, if anyone, is being harmed by genetic engineering? Is it an individual, a company, the environment, a financial situation, or a strongly held belief or doctrine. Everyone actively concerned with the pros and cons of genetic engineering practices and education should accept three responsibilities: Obtain more information and understanding about the impact of molecular techniques, both basic and applied; evaluate the perspectives and motives of those on both sides of an issue, which may include religious, financial, or scientific viewpoints; and finally, be an active participant in discussions of biotechnology ethics and policy to alert others that it maybe important for everyone.

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DISPERSAL OF BLACK VINE WEEVIL ADULTS, *OTIORHYNCHUS SULCATUS* (F) IN IDAHO HOP YARDS (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT—Movement of adult black vine weevils, *Otiorhynchus sulcatus* (F), was studied from June through August of 1990 in an Idaho hop yard using mark, release, and recapture techniques. Eighty-six of 556 (15.5%) marked black vine weevil adults were recaptured. Very little dispersal occurred in June as most recaptured weevils (98%) were found at their point of initial capture/release. Higher frequency of movement and greater distance moved was noted with weevils recaptured in July and August. Maximum distance moved was 35 meters. Pest control tactics employed after adult emergence in June are unlikely to be affected by black vine weevil dispersal.

Keys words: Black vine weevil, dispersal, capture and release, hops.

INTRODUCTION

The black vine weevil, *Otiorhynchus sulcatus* (F), is an important pest in commercial hop yards in Idaho. Overwintering larvae cause the most serious damage by feeding on hop root systems; however, control efforts must be directed toward adult weevils after emergence from the soil in late May but before egg laying in mid-June. Although many aspects of the biology of this pest in Idaho have been reported (Baird et al. 1992), evaluation of control efforts has been hampered by the lack of knowledge of adult weevil dispersal. Acknowledged by researchers to be flightless (Essig 1933, Shanks 1991), black vine weevil adults disperse only by walking or by being mechanically transported with plant materials or field equipment. Garth (1977) reported adult black vine weevils moved <6 m in Washington strawberry fields and Maier (1978) indicated most adults moved <10 m from their original site in a Connecticut residential area. The purpose of this study was to gather information on black vine weevil dispersal behavior to better evaluate our efforts to control adult weevils in Idaho hop yards.

MATERIALS AND METHODS

Adult black vine weevils were collected from an infested hop yard (cv. Galena) near Greenleaf, Canyon County, Idaho. Soil sampling was done by screening and examining soil and plant debris to a depth of 10 cm in a 60 cm circle around hop plants. Initial capture and marking sites were noted and used as reference points for subsequent sampling efforts which were conducted weekly for nine weeks (6 June-10 August) at various times from 0600 to 2300 hr. The initial capture/release sites for each weevil were the first sites for follow-up sampling which was conducted in the eight ordinal directions from the initial capture site. Captured weevils were refrigerated at 10°C overnight and then marked for identification with fast-drying enamel model paint prior to release the next morning. All weevils were released at their original site of capture. Subsequent recaptures were noted and the distance traveled was measured and recorded. Distance traveled by marked adult weevils was measured as a straight line distance from the hop hill where initially captured to the recapture point.

RESULTS

Eighty-six (15.4%) of 556 marked weevils were recaptured through the study. During the first three weeks (6-27 June), 55 were recaptured with only one weevil having moved from its original capture site. During the second three weeks (28 June-16 July), 17 additional marked adults were recaptured with an average movement of 5.9 m from the original capture site. During the third three week period (17 July-10 August) 14 recaptures were recorded with an average dispersal distance of 9.8 m (Table 1).

Nearly 69 percent (59) of the 86 recaptured weevils were associated with the same hop plant under which they were released (Table 2). However, this behavior pattern changed as summer progressed. Ninety-eight percent (54 of 55) of the 6-27 June recaptures, 24 percent (4 of 17) of the 28 June-16 July recaptures, but only 7 percent (1 of 14) of the 17 July-10 August recaptures were associated with the same hop plant (no movement from initial capture/ release site). The maximum distance traveled by any adult black vine weevil was 35 m. Of the 27 recaptured weevils that moved from their original capture site, the mean distance was 9.2 m.

Weevils marked with enamel paint and maintained in the laboratory showed no mortality during the study. The same marking and handling techniques used on field released weevils similarly had no apparent effect on adult mortality.

Table 1. Percent of Black vine weevil recaptured and mean distance traveled.

Release/Recapture Dates	Number BVW Recaptured of 556 Initially Captured/Released (% of Total Recaptures)	Percent Recaptured BVW Associated With Same Hop Hill (No Migration)	Mean Distance Traveled (Meters)
6-27 June	55(64%)	98.2	.04
28 June - 16 July	17(20%)	23.5	5.9
17 July - 10 August	14(16%)	7.1	9.8

Table 2. Dispersal distances of individually marked black vine weevil adults in 2 m increments.

	Number in Each Distance Class (Meters)								
Release/ Recapture Intervals	0	2-3.9	4-5.9	6-7.9	8-9.9	10-11.9	12-13.9	14-15.9	>16
6-27 June	54	1	-	-	-	-	-	-	-
28 June - 16 July	4	5	1	-	3	1	-	2	1
17 July - 10 Aug	1	2	2	4	1	2	-	-	2

DISCUSSION AND CONCLUSIONS

The recapture rate of marked weevils was higher (15.4%) in this study than for Maier (1978) who reported that 5.7 percent of marked weevils were recaptured. Infestation of hop yards by black vine weevil occurs most often from transfer of infested root stocks; however, adult movements observed during this study demonstrate the capability of the weevils to walk sufficient distances to infest adjacent yards. Garth (1977) and Shanks (1991) noted similar observations in Washington strawberry plantings. The wide host range, >200 recorded in the literature, also contributes to the ability of *O. sulcatus* to spread and establish a population in a new area.

Our findings on black vine weevil movement are similar to those in other studies. Also, Garth (1977) indicated black vine weevils in strawberries moved only short distances (<6 m). Maier (1978) reported most weevils moved <10 m (maximum = 85 m) in a Connecticut residential area with an increasing dispersal distance as the season progressed from July (6.9 m) to September (31.2 m).

In this study, dispersal of *O. sulcatus* adults was minimal during June when feeding activity is the greatest. Frequency of movement and distance moved increased dramatically in July and August. This pattern of mid-to-late season dispersal coincides with oviposition, thus contributing to the spread of the species within and between hop yards and to other non-hop host plants. Pest control efforts in commercial hop yards are minimally affected by natural dispersal since adult weevils remain localized during mid-to-late June when control efforts are made.

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We are especially pleased to feature the proceedings of the following Symposium in this issue of the Journal of the Idaho Academy of Science. The Symposium was held as a part of the 1992 Idaho Academy of Science members' annual meeting.

Among the papers presented herein, that of Holte, was formed largely from tapescripts taken during the oral proceedings. All other papers printed here are from manuscripts sent our office subsequent to the Symposium. Additionally, the paper by Fields was not presented during the Symposium (but given at a different session); the committee, however, deemed it particularly appropriate to include it in view of the commonality of the subject.

We are much indebted to Dr. D.H. Mansfield for organizing and coordinating the Symposium, and significantly contributing to its publication here.

The Editor

BOONE SYMPOSIUM ON IDAHO BOTANY: INTERPRETING IDAHO'S BOTANICAL HERITAGE

INTRODUCTION

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About one year ago the idea emerged to have an Idaho Academy of Sciences Symposium focusing on botanical themes and issues. Because this is the Centenary year of Albertson College of Idaho, the Symposium is entitled the "Boone Symposium on Idaho Botany" to honor the contributions of Dr. William Judson Boone—founder and first president of the College and an avid botanist. In this historical context, the theme of this afternoon's symposium is: Interpreting Idaho's Botanical Heritage.

Idaho often seems to be peripheral to many botanical treatments. Beginning students of botany are particularly frustrated by this. We are located at the southeast edge of the "Northwest" in the **Flora of the Pacific Northwest** and at the north edge of the **Intermountain Flora**. There are some questions that I would like you to ponder as the symposium proceeds. 1) How does the study of plants in Idaho relate to what is going on around us? Dr. Ron Hartman from University of Wyoming may offer some insights. 2) How do we, as Idaho botanists, interpret our rich botanical heritage? Several papers should help us with this, in particular those of Drs. Pat Packard, Doug Henderson, and Karl Holte. 3) Is there a need for an Idaho Flora? Regardless of the answer to this question, how do we coordinate our efforts to face the wealth of questions posed by Idaho botany given the resource limitations we inevitably encounter? Some suggestions are evident in the work of Dr. Barbara Ertter and Mr. Bob Moseley.

As you learned this morning, Dr. Arthur Cronquist, our scheduled keynote speaker, passed away Sunday. The Keynote address is presented by Dr. Del Wiens of University of Utah on Endemism, Rarity, and Extinction in Plants. It is preceded by a tribute to Dr. Cronquist by Barbara Ertter, who did her Ph.D. work with Dr. Cronquist. The Boone Symposium on Idaho Botany and these proceedings are dedicated to Dr. Cronquist.

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A BRIEF LOOK AT WILLIAM JUDSON BOONE AND HIS CONTRIBUTIONS TO THE STUDY OF BOTANY IN SOUTHWESTERN IDAHO AND SOUTHEASTERN OREGON

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Since I teach English, I find the title of this talk no more offensive than "Lines composed a few miles above Tintern Abbey on re-visiting the banks of the Wye during a tour, July 13, 1798." Let the comparison stop here, for to protract a discussion of the similarity of the contents of these remarks to the magnificent poem of Wordsworth's would not redound to the credit of this presenter.

In the time allowed I want to outline Boone's contributions under two convenient but by no means mutually exclusive topics—Boone's background, training, and work as a botanist—and Boone's career as a teacher.

If there are those here who do not know of this remarkable man, I must offer a few bits of biography. He was born in western Pennsylvania on November 5, 1860, on the Monday before Abraham Lincoln was elected 16th president, Tuesday, November 6. After attending various country schools (McNary school township; Hickman's Old Pike School) he enrolled at Elders Ridge Academy, a Presbyterian institution, to which he brought a good mind that inclined to look at problems in ways that his biographer characterizes as seeing things from a different angle. And he also brought the skills of woodcraft, for with an axe and maul he helped make fence rails, and with a ten pound Kentucky rifle, a muzzle loading shotgun, and a fishing pole, he helped keep the kitchen back home supplied with food.

From Elders Ridge, he went on to the College of Wooster, a school chartered in 1866 but where teaching did not begin until after an endowment had been secured in 1870. Boone enrolled in the fall of 1880, in the school with an enrollment of 178 spread through the four classes. If this figure seems small, re-read ***The Education of Henry Adams*** and smile at the size of the Harvard class of 1858 with not quite a hundred students. Perhaps a student body of not quite 400 existed there then.

It was at Wooster he was introduced to the study of botany and to performance in athletics, particularly baseball and football, and in music on the violin. After graduating from Wooster, Boone attended Western Theological Seminary at Pittsburgh, graduating in 1887 and facing the choice of undertaking missionary work either in Idaho or Persia, choosing the former because "home missions work in harder," he once wrote, "and there is less glory in it than in foreign missions." He had heard the noted missionary Sheldon Jackson address Western Seminarians urging students to go to "the unpromising fields of the West."

After graduation he was dismissed to the Presbytery of Wood River, and Wooster Presbytery minutes say further "that the stated clerk was directed to furnish him with the necessary testimonials." Presbyterians use a strange jargon.

On November 9, 1887, eight days after William Judson Boone and Annie Jamison were married, the couple—he 27, she nearly 24—arrived in Caldwell where he would become the new Presbyterian minister in the town scarcely four years old. After serving first as "stated supply" pastor, and as pastor, Boone was named to the Board of Managers for The College of Idaho, a board charged with taking the necessary steps to open the school in the fall of 1891. Two years later, Boone, facing increasing obligations as president of the new school, resigned his pastorate, becoming a full-time executive and teacher, concentrating eventually upon botany which he taught for nearly 45 years.

All that out of the way, I now turn to the first of those topics adverted to earlier, Boone as a botanist. His biographer (H.H. Hayman) reminds us that Boone's academic preparation for botany was limited to the instruction he had received at Wooster. You all know better than I what the state of instruction in botany was in the last quarter of the 19th century. His natural interest and his logical mind led him to become a leading botanist of the Rocky Mountain area, says his biographer. I can only put him in the same class as those sometimes—usually—superb Britishers who, as amateurs, do the most amazing professional work.

In 1887, when Boone arrived in Idaho Territory, the plant life had not been thoroughly analyzed and classified, and that, says his biographer, was Boone's job. Since intrusive grazing had not yet begun, and since the major botanical surveys were not yet completed, a few minutes' hike from the old campus downtown to Indian Creek or Canyon Hill produced specimens of camas, hyacinths, rooster bills, bluebells, violets, Indian paintbrush, larkspur, buttercups, and dozens more.

But as grazing intensified, and as cultivation followed the development of irrigation, Boone observed a continual change in plant life...the disappearance of old species and the invasion of chicory, ragweed, puncture vine, sandburs, white top, and morning glory, among others.

He said once as he gazed over collecting grounds for certain plants now gone forever, "Well, civilization is a great thing, but it's awfully hard on a naturalist." (H.H. Hayman).

One of Boone's resources was P.A. Rydberg's ***Key to the Rocky Mountain Flora***, containing over 5,000 plants. In the margins of the book, Dr. Boone made his notes, recording dates and places where he had collected, a record of 20 years or so. With this book and his notes, he could tell whether a plant was a new one to him or one he had previously collected. About five or six weeks before he died (July 8, 1936) he lost the book, and so far as I know it was never found.

He was an avid collector of mushrooms and quite adept at preparing the edible varieties. One bit of folklore has it that customarily after braising an unfamiliar specimen in butter he would try it out on his cat before eating any of it himself. The item concludes: "And he used the same cat for many, many years."

I quote Dr. Hayman, Boone's biographer, at this point:

> "In his correspondence with Professor Harold St. John...Pullman...one learns something of the wide range of his knowledge. Professor St. John mentioned, "I have worked over your **Eriogonum** from Weiser-Midvale. It is certainly not in Rydberg nor any other of the standard books." He sent this species to Tidestrom for further analysis and classification. (When) "St. John was preparing a manuscript of a book on botany" he asked to borrow Boone's herbarium material on these plants. Indeed, Boone's significant work in botany was two-fold — in taxonomy, and in the teaching of botany."

This is the second topic I wish to discuss, and the bored as well as the preferred auditor will recognize an approaching conclusion.

As a teacher Boone was a phenomenon, not a passionate presence, not a scintillating showman, but a well-organized, disciplined, challenging figure. The recollections of his former students agree that his introductory botany class was one of the courses a person going through The College of Idaho had to take. His grade book often listed 90 or more, a large class, indeed, at least one quarter of the student body. And he needed help managing such a large class. His student assistants often went on to distinguished careers in science and medicine. I'll mention only a few, and as I identify them I want to point out a kind of apostolic succession that seems quite evident to me. Having utilized liturgical vocabulary, I should say here that Boone was a profoundly religious man to whom the Bible was neither a book of magic nor a scientific treatise.

One of his first and best lab assistants was Harold Tucker, class of 1923. After teaching biology at Caldwell High School for eight years, Tucker returned to The College of Idaho and taught until his death in 1959. Tucker was a superb teacher and expedition leader. Another lab assistant was Lyle Stanford, class of 1933, who returned to his alma mater with a Ph.D. in zoology and to a brilliant career.

One of Harold Tucker's bright students was a young woman named Patricia Packard. After her graduation in 1949, Dr. Packard took her Ph.D. in botany and returned to teach at the College, retiring after a productive career here. I shall mention only two of her many students who have gone on to distinguished careers, Dr. Jim Grimes and Dr. Barbara Ertter.

The program begun by Dr. Boone, who redirected his hunting and fishing energies—well, not entirely the fishing—into a love for the outdoors, climaxed in a tradition of field trips and a strong biology program that is not just still alive, but one that, if I can end these remarks on a rather bad botanical pun, that is positively flourishing.

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TRIBUTE TO DR. ARTHUR CRONQUIST

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I begin, for the benefit of any non-botanists in the audience, by telling you who Arthur Cronquist was, why it was considered to be a major coup by the symposium planners that he agreed to be our banquet speaker, and why the word that he was coming to Idaho passed so excitedly through the network of local botanists and native plant enthusiasts. For a start, he was senior scientist at the New York Botanical Garden, which (although Harvard and the Missouri Botanical Garden might disagree) is the biggest and most active herbarium in the country. As such, he was one of the top botanists in the world, scheduled later this year to go to Berlin, St. Petersburg, and London (there had also been tentative plans for Vladivostok, until it became apparent this was not a good year to go).

Cronquist's main claim to fame was being one of the authorities on the systematic arrangement and evolution of flowering plant families. His system, the Cronquist System, is now used in the College of Idaho herbarium, and many others. He was also an authority on the Compositae or Asteraceae family, one of the largest and most complex families including daisies, thistles, and dandelions. He wrote the treatment of this family and many others for most major United States floras, and was a primary author of the ***Vascular Plants of the Pacific Northwest*** and ***Intermountain Flora***. His awards were numerous, including the prestigious Asa Gray award and Linnaean Medal. One measure of his stature was the frequency he was selected as a favorite target by 'up-and coming' young botanists trying to establish merit by attacking previous authorities.

This brings us to the second question: why, if Cronquist was so world-famous, was he coming to little ol' Idaho? Why was he considered not only a noteworthy but a perfectly appropriate banquet speaker for a symposium on Idaho floristics, honoring Idaho's first resident botanist (William Judson Boone, founder of the College of Idaho)? Sad as his death is, there is a symmetry here, in that Cronquist's career ended when he was on his way to be an honored banquet speaker in the state where his career began.

Karl Holte quoted from Ray J. Davis's memoirs earlier this afternoon, recalling a certain tall, slender, enthusiastic Boy Scout with a talent for plants, the "big blonde Swede" in Pat Packard's terminology. Art Cronquist was born in San Jose, California, 19 March 1919, and grew up in Portland, Oregon. By the time of high school, he was living in Pocatello. He took his first taxonomy class from Davis at Idaho State University. The story goes that every student in the class was supposed to choose a family on which to do a project. Being by and large range majors, the two top students both wanted to work on grasses. They flipped a coin (or the equivalent), and the loser settled for Compositae.

Although Cronquist transferred to Utah State University, where he obtained a B.S. in 1938 and an M.S. in 1940, his involvement with the Idaho flora continued. In 1937, he worked for the Forest Service in Dubois, Idaho, and from 1939 to 1941 supported himself partly by the sale of plants collected in Idaho.

His interest in Compositae continued with a special interest in *Erigeron*, the subject of his doctoral work at Minnesota (where he was a student of L.O. Rosendahl, who was one of Engler's last students). He began serving as a curatorial assistant at the New York Botanical Garden a year before his Ph.D. in 1944, working on Simaroubaceae for Merck Pharmaceutical company (looking for quinine substitutes) and on Sapotaceae for Chicle company (looking for chewing gum substitutes). This was during the war years, when many usual supply sources were out of reach. Cronquist, himself, had been excused from military service because of a dislocated elbow.

From New York he went to Georgia, then Pullman, then Brussels, and finally back to New York, this time to stay. One of his anecdotes from his time at Washington State University in Pullman involved returning from lunch to find a note on his chair, "Christ came to see you"; he was understandably relieved to find out this was John Henry Christ [short 'i'], a prolific collector of the Idaho flora. He was, alas, let go from Pullman as the most recently hired during a period of faculty cut-backs.

Fortunately, the New York Botanical Garden was a primary center for working on floras of the United States, including the Far West. After finishing Compositae for Ray Davis's ***Flora of Idaho***, Cronquist collaborated in the production of ***Vascular Plants of the Pacific Northwest***. He was senior author of ***Intermountain Flora***, which is still being written. Fortunately for us, he finished the volume on Compositae last year; he was working on *Mentzelia* for the next volume at the time of his death.

Cronquist definitely retained a soft spot in his heart for Idaho, and for the West in general. Whenever I went to his office he invariably spent the first few minutes reminiscing about Idaho before getting down to business. Several times while I was a graduate student at New York I would sneak into the New World Desert Section of the conservatory and smuggle out a sprig of sagebrush , which I would take to Cronquist, Pat and Noel Holmgren, and Rupert Barneby; we would all take a big sniff and dream of the West. I also remember when the movie "Electric Horseman" came out, the only movie I'd seen that really showed the beauty of sagebrush country. I talked Pat and Noel Holmgren into going; Cronquist was tempted, but just couldn't bring himself to go to a movie with Jane Fonda in it.

A couple of days ago I talked to Pat Holmgren (Director of the Herbarium at New York Botanical Garden) and Cronquist's wife Mabel, trying to find out what his feelings were about coming to Idaho as our banquet speaker (he was looking forward to it) and what he would talk about (proposed title: 'Recollections of Botanists and Botanizing in Idaho'). I could practically recreate his talk based on the anecdotes for which he was notorious. I'd tease him at the lunch table in New York by calling out "That's number 237" when he began an oft-repeated anecdote. It never stopped him; he'd just laugh, his deep belly-laugh, and then continue unfazed.

He would undoubtedly have started out with the last time he was in Caldwell when the barber cut his eyebrows: Cronquist was very proud of his distinctively bushy eyebrows, one curving up and the other down. It's too bad he wasn't able to come to Caldwell again to get some different anecdotes to remember it by. He would also recall the time he was in the Centennial Mountains and dropped south off a ridge to find himself in Montana; there is a place where the state line doubles back so that it's possible to do that.

Mabel told me another anecdote that I don't recall hearing before. She was camping with Art in Idaho when they heard an owl hoot. Art hooted back, the owl hooted again, Art hooted back again. It kept up until the owl flew into the clearing, landed on a post, and hooted again. Art kept still, and the owl flew towards him, nearly landing on his head if Mabel hadn't shooed it away. When Art protested, Mabel sensibly noted the wounds that the owl's talons would have caused, to which Art replied, 'Ah, but think of the story I could tell with the scars to prove it!'

Cronquist would have regaled you with stories of early Idaho collectors, as well as his own exploits: and then, if the audience had been right, he would have tried to get you all to sing along with him 'And here we have Idaho', which he frequently sang whenever he reminisced about Idaho. I'm afraid I can't pull that off myself; if you want to sing to yourselves, however, it would be a tribute he would appreciate.

He was a neat person, and I miss him. I wish all of you could have met him.

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RAY J. DAVIS — LIFE HISTORY

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I am pleased to see so many people at a botanical meeting at the Idaho Academy. I have prepared an easel with some pictures of Ray J. Davis. Because of the size of this auditorium, I have set the easel in the hallway entrance so you can look at the pictures as you leave the auditorium.

An earlier speaker told us that Boone was a botanist "B.C." and that Davis was a botanist "A.C." — that is, "Before Cows" and "After Cows". That speaker emphasized that cows do change the flora. Ray came to Idaho considerably after cows came here.

He was born in 1885 on a farm near Provo, Utah. In his autobiography he mentioned that he was glad polygamy had existed, because his grandfather had married three women and he (Ray Davis) was a descendant of the second wife. Ray himself also had three wives, but not all at the same time. The first wife died rather tragically of bone cancer. His second wife died shortly after they had taken a trip around the world. His third wife is still alive.

He went to kindergarten, grade school, and high school in Provo, Utah. According to his obituary, he attended Brigham Young University a "record number of years," ultimately doing a year and one-half of graduate work there. He completed the rest of his graduate education at the University of Wisconsin where he received his Ph.D. in 1924.

His autobiography refers to a graduate examining committee of eight people which allotted a full day for each doctoral examination. The first candidate passed. The second and third students (one of which was a woman) did not pass. Ray was the fourth examinee and they quizzed him for five hours. Exhausted from that ordeal, he grasped the stair railing and subsequently did not remember going down the steps and out the door before he just collapsed on the lawn. He did not find out that he has passed for two days. He didn't know whether he should attend classes or go back home. Finally, he asked one of the professors, "What happened? Did I pass or did I not pass?" The professor said, "Oh yeah, didn't one of the other professors tell you?" Nobody had told him that he had passed. Ray then said "How could you pass me? I only answered about one-third of the questions in an hour." The reply was, if he had answered any of the other questions, they would have known he was bluffing because they were questions to which no one knew the answers! Hopefully, oral examinations are not that tricky in this day and age.

After graduation, Ray worked for three state agricultural experiment stations. But he wanted to come back West and thus started teaching high school at Snowbird, Utah. He taught recreation, agriculture, and several other subjects and was also a coach. He was so successful at coaching that Dixie College asked him to come there to coach.

In the summer of 1930 Davis was hired from Ricks College to join the faculty of the University of Idaho - Southern Branch in Pocatello. He was offered $500 to collect plants during the summer before he began his teaching position in Pocatello, to add to the collection at the Southern Branch. Because he was still an employee at Ricks, however, the state decided they could not pay him. Instead, one of the deans bought the plants for $500. That was the only payment he ever received for any of his plant collecting. Funding in general was tight. When he asked for some cabinets, he was given two small ones that were of the type used for mammal collections. He gradually collected cabinets as years passed. He even had to buy his own mounting paper and labels. His family prepared the labels and mounted the plants. He wrote:

> "For 12 summers without benefit of professional assistance or financial help, I made a systematic collection of all the plant species that I could locate in Idaho. There was no place in the state more than 50 miles from where we collected from every life zone."

His collections of plants from East Central Idaho are sparse. This may not be so surprising, however, considering budget limitations and the fact that he collected so extensively all around the state.

He seemed to love the entire process of planning systematic collecting trips, the actual collecting, and identifying the plants. In his magnum opus, ***The Flora of Idaho***, he made references to the "wonderful outings in the hills in the name of science." He said that they were wonderful not only for him, but also for his two older sons, Jay and Hal, who grew up camping, sometimes all summer long, and were able to visit historic places, learn the geography and history of the state, and meet exciting characters such as gold miners, lumberjacks, cowboys, foresters, and sheepherders of the Idaho back country. They also enjoyed a little swimming, fishing, and rock climbing. The boys became men in the process. Their pride in their dad and their knowledge of the manner and extent of his contribution to ISU are among the byproducts of the story of the origin and development of the Ray J. Davis Herbarium.

Remember that this was during the Great Depression and before the advent of the National Science Foundation and Team Research Grants. Between his collecting, gifts, and trades, Dr. Davis acquired over 50,000 mounted specimens of plants which are now the nucleus of the Idaho State University Herbarium.

A few years ago I requested that the herbarium be named the Ray J. Davis Herbarium in his honor.

Ray and family collected plant specimens from where they grew in mountains, deserts, wetlands and forests. Dirt was removed from the roots and the plants were transported in a metal container called a vasculum. (This was before plastic bags.) Back in camp, the plants were placed between folded newspapers which were then placed between alternating blotters and cardboards, just as we do today. He did not have a nice drier as we do now, however.

Processing the plants was initially a family affair. For the first two years, Ray's wife, Nora, mounted them on to the 12 x 18 sheets of 100% rag content paper. As the family grew, so did Nora's obligations at home. Later, he put his grade-school-age sons, Jay and Hal, to work mounting plants. The college (University of Idaho Southern Branch, at that time) ultimately paid them 25 cents an hour for shaking the dirt off the plant roots, placing the whole plant specimen artistically on stiff mounting sheets, and carefully taping them into place. Delay in mounting occasioned by funny paper reading was not tolerated, but did not fully halt until Ray J. quit using the comic sections for collections.

Later, university students working for the National Youth Authority did the mounting. When that organization folded, student and secretarial help was recruited. Dr. Davis always attempted to identify plants in the field and jotted down on newspapers his first impressions. He also filled little red notebooks with field notations. When his botanical papers were sorted after his death, these notebooks were discarded. I have had several requests for them by people trying to locate data about where plant populations occurred then, but unfortunately, they are no longer available.

In his laboratory in Baldwin Hall (later to become the Idaho State University Chemistry building), he re-examined the plants for further consideration. When the Chemistry Department needed additional space for expansion, the herbarium was moved to what is now the ISU Administration building. Later yet, it was moved to what is now the Charles Kegel Liberal Arts building. After Ray J. Davis retired in 1965 and I became curator, the herbarium was moved to the new Biological Sciences Building in the Larry Gale Complex. Finally, it resides now in the Idaho Museum of Natural History, at first in the basement and in 1992 moved up to the third floor. This last move was because it was not a question of if a basement would flood, but when and how often. The collections are pretty safe now because Pocatello hasn't had the kind of flood that would reach the third floor since the Lake Bonneville Flood 16,000 years ago.

Davis sought the advice of several other experts, such as Dr. Arthur Cronquist, Mary Ann Olenby, J.H. Christ, and Rexford Daubenmire in the identification of taxonomically difficult groups. Ultimately, about 72 botanists helped him to put together the book ***Flora of Idaho***. For additional information he visited several other herbaria such as the Missouri Botanical Gardens of St. Louis, the Smithsonian Institution in Washington D.C., Harvard University Herbarium, and the Philadelphia Academy of Science. In Philadelphia, he said, he was first able to examine the Lewis and Clark Collection.

Ray Davis published a total of five books. One most recent contributions was the ***Ecology and Conservation of Natural Resources*** which he published for high school and is now in its second printing. He also wrote ***Autobiography of a Schoolteacher***, which contains pictures of his life and of his family. One of the most popular books he wrote, the royalties from which financed at least one trip around the world and possibly two, is ***The Field Guide to the Rocky Mountain Wildflowers***, co-authored by Drs. John and Fred Craighead. Dr. Davis said that he did the botanical descriptions and the Craigheads did the interesting facts about which animals used the plants, where they grew, and how **Homo sapiens** used them. Of primary importance was the *Flora of Idaho*, which is 832 pages, first published by Brown and Company of Dubuque, Iowa. When they lost interest in reprinting it, Ray convinced them to give the plates to BYU Press, which republished the book.

Another interesting book he wrote was ***Believe 'em or Not***, which is a collection of tales about his true adventures in the outdoors when he was a teacher at various institutions. After I read that book, I thought this man was lucky to have lived to be eighty-nine. He did things such as taking a class up to the Tetons and instead of hiking down through a ravine, the slow way down, they all slid down a glacier, sitting straddled together in a chain. They slid for about a mile until it leveled out. The group broke apart and some tumbled down head over heels; others rolled for at least a half mile. When they got to the bottom, he said, nobody moved. He thought they were all dead, but he knew that HE was still alive. He first went over to one of the thirteen girls in the group and sat her up. She was so dazed she couldn't even sit up alone. When he saw she was all right, he went one by one through the group and got them all sitting up and talking. Finally, one of the girls started to laugh and pretty soon they were all laughing hysterically (which they probably were). One of the girls said, "You know, I wouldn't take a thousand dollars for that slide, but then I wouldn't do it again for a thousand dollars either." This book is really hilarious; I stayed up most of a night reading it.

In addition to the books, he published two significant papers, both in the journal ***Brittonia***. One was published in January 1966 and was about chromosome numbers in *Claytonia*, a genus in which he specialized. The second concerned the North American perennial species of *Claytonia*.

From reading Ray J. Davis's autobiography and other materials he has written, I became impressed with his dedication and versatility. In addition to his years of collecting plants throughout Idaho, he worked twelve summers as a ranger in Yellowstone Park. He also served for a time as president of the Idaho Academy of Science. He was very active in many other activities, such as serving in the Idaho State Legislature and on the Pocatello City Council. Additionally, he worked with Boy Scouts for forty-five years. His greatest joy, however, seemed to be from teaching.

The prologue to his autobiography reads as follows:

> "Was I a typical schoolteacher? I don't know. I do know that I had a good life teaching. Of course, I had my times of frustration and disappointment.

Forty-three years in the classroom and laboratories have brought their rewards. Maybe not in money, but in other ways that money can't buy. I fondly remember a tow-headed, slender Boy Scout at camp one summer that I interested in flowers. I followed him through high school, taught him in college, collected plants with him on trips, saw him with pleasure when he received his doctoral degree and now I see him as one of the world's recognized great botanists." (Arthur Cronquist)

"Money can't buy the satisfaction I get from the students. Of course, all my students did not turn out this well. They were an average group - some good, some poor. Most of them were just good solid citizens. I have forgotten some of them, but the majority of them I still remember and I swell with pride when I read of some worthy accomplishment by one of them and am thrilled when I meet them again. Yes, life has been good to me."

Davis is commemorated by two plant species names, *Cirsium davisii* Cronq. and *Hackelia davisii* Cronq. both appropriately Idaho endemics.

I think my friend, the late Emeritus Professor Pierre Pulling, summarized Dr. Ray Davis very well when he said, "Ray J. Davis was a gentleman, a Christian and a scholar."

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THE ROCKY MOUNTAIN HERBARIUM, ASSOCIATED FLORISTIC INVENTORY, AND THE FLORA OF THE ROCKY MOUNTAINS PROJECT

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ABSTRACT—The growth of, and improvements to, the Rocky Mountain Herbarium (RM, RMS, USFS) are reviewed with emphasis on the goals of the program. The intensive and systematic floristic inventories carried out in recent years by the RM in Wyoming and adjacent states are discussed, as are plans to complete the survey of the vascular plants of the region. Finally, an update is provided on the Flora of the Rocky Mountains project, including interactions with other similar projects, circumscription of the area covered, contents (particularly of the first volume), and contributions by specialists. To this end, the Rocky Mountain Flora Association is being established to coordinate the inventories and the databasing of specimens and to help with the preparation of the taxonomic treatments.

INTRODUCTION

I was asked to present a talk on the Flora of the Rocky Mountains project, but felt it necessary to expand the topic to include discussions on our recent floristic inventories in Wyoming, Idaho, Colorado, and New Mexico, and the significant changes which have occurred at the Rocky Mountain Herbarium (RM) over the past 15 years. Thus a more complete picture emerges of the project's origin, resources, and goals. Although the flora of Idaho is touched on but briefly, I feel that the inclusion of the last two topics may provide helpful information to those involved in similar work in that state and elsewhere.

THE ROCKY MOUNTAIN HERBARIUM

What is now called the Rocky Mountain Herbarium (RM) was founded by Aven Nelson in 1893. It was so designated by the Board of Trustees of the University of Wyoming (UW) in 1899, following Nelson's successful botanical exploration of Yellowstone National Park. Since 1960, it has been housed on the third floor of the Aven Nelson Building. This edifice was built in 1923 for the University Library and School of Law following Nelson's tenure as UW president (1917-1922). For a detailed history of the Herbarium, mostly prior to the mid-1950s, the reader is referred to the excellent biography ***Aven Nelson of Wyoming*** by Roger L. Williams (1984). Aven Nelson was Curator of the Herbarium for nearly 50 years (1893-1942). He was succeeded in this position by Cedric Lambert Porter (1942-1968), John R. Reeder (1968-1976), and Ronald L. Hartman (1977-present). The following discussion will focus primarily on the past 15 years, the period of my tenure as Curator.

The staff of the RM includes myself (nine-month contract; 30% time as Curator), B. Ernie Nelson, Herbarium Manager since 1974, who does an admirable job of filling a crucial role in the daily operations (full-time), and part-time help. We normally employ three to six students per semester working 10-20 hours per week. They are involved in various aspects of processing specimens including label typing (and databasing), the mounting of specimens (we average about 13,000 per year), accessioning, updating the Wyoming dot maps, filing, and the processing of loans and exchanges.

Over the years, the RM has grown gradually through the efforts of staff and graduate students in obtaining specimens from throughout the Rockies. Major spurts came with the integration of the George E. Osterhout (20,000 sheets in 1937), the Hapeman (30,000, 1951), the Wilhelm G. Solheim Mycological (RMS, 48,000, 1978), and the U.S. Forest Service [National] (USFS, 120,000, 1982) herbaria. In 1978, an intensive and systematic floristic inventory of Wyoming and other Rocky Mountain states was initiated. To date the program has obtained 192,000 numbered collections and possibly an equal number of duplicates for exchange. Acquisition of specimens through the inventory and from the RMS and USFS has more than doubled the size of the Herbarium (Fig 1).

The RM is the largest facility of its kind between the University of Minnesota (St. Paul), Missouri Botanical Garden (St. Louis), and the University of Texas (Austin) to the east and the University of California (Berkeley), the California Academy of Sciences (San Francisco), and Rancho Santa Ana Botanic Garden (Claremont, CA) to the west. It ranks 18th in size based on number of accessions of over 630 herbaria listed in Holmgren, Holmgren, and Barnett (1990) for the United States; 8th in size for a state university. If one includes either the number of specimens in our backlog (70-80,000) or the number of specimens in the Range Management Herbarium (WYAC; 60,000) of the College of Agriculture, we would rank 16th overall or 7th for a state university. The combined herbaria (RM, RMS, USFS, WYAC) plus the backlog total 750,000 specimens.The WYAC includes the 50,000 accession, A.A.Beetle Grass Collection, with a good representation of graminoids from throughout the World.

In order to house the expanding holdings of the RM, a National Science Foundation facilities grant ($238,859, to R. L. Hartman and Meredith A. Lane, Acting Curator 1985-86) was obtained in 1986 for the purchase of a manual-assist SpaceSaver mobile storage system and 100 new cabinets (since 1977, 26 new cases have been provided by UW and 80 old cases were acquired with the USFS). The system consists of two modules, one with eight movable and three stationary rows (holding 230 standard herbarium cases), the other with five movable and two stationary rows (holding 122 cabinets). This system has increased by 60-70% the storage capacity on the south half of the Herbarium. There are an additional 83 cabinets not in the system, the majority of which are in the north half of the RM. The NSF grant also provided funds to hire a number of undergraduates to facilitate the move, reorganize the collection, and help with the backlog. The reorganization consisted of the following: accessioning and intercalation of the USFS into the RM, replacement of many of the genus covers, segregation of Rocky Mountain area specimens (yellow folders; excluding Wyoming's, red folders) from extra-regional sheets (manila folders), and reordering of plant families from the antiquated Engler-Prantl system to one which is alphabetical within major groupings (algae, fungi, mosses/liverworts, lichens, ferns/fern allies, gymnosperms, monocots, and dicots). This reorganization and the processing of new acquisitions has also been facilitated by new funding from the U. S. Forest Service's Rocky Mountain Range and Experiment Station (since 1982) and the College of Arts and Sciences, UW (since 1986).

Despite the growth of the Herbarium, there is still ample work space for processing of specimens, plant identification, herbarium research (seven work areas each with a dissecting microscope), for the geographic information system (GIS), and for ancillary items (extensive microfiche, reprint, map, and gazetteer collections, library, light table, three microcomputers with printers, literature, type, and Wyoming dot map card files, etc.). A Wyoming reference collection (containing a representative specimen of each taxon of vascular plant known to occur in the state, initially assembled in 1978) is conveniently located to facilitate identification, thus reducing handling of the research material.

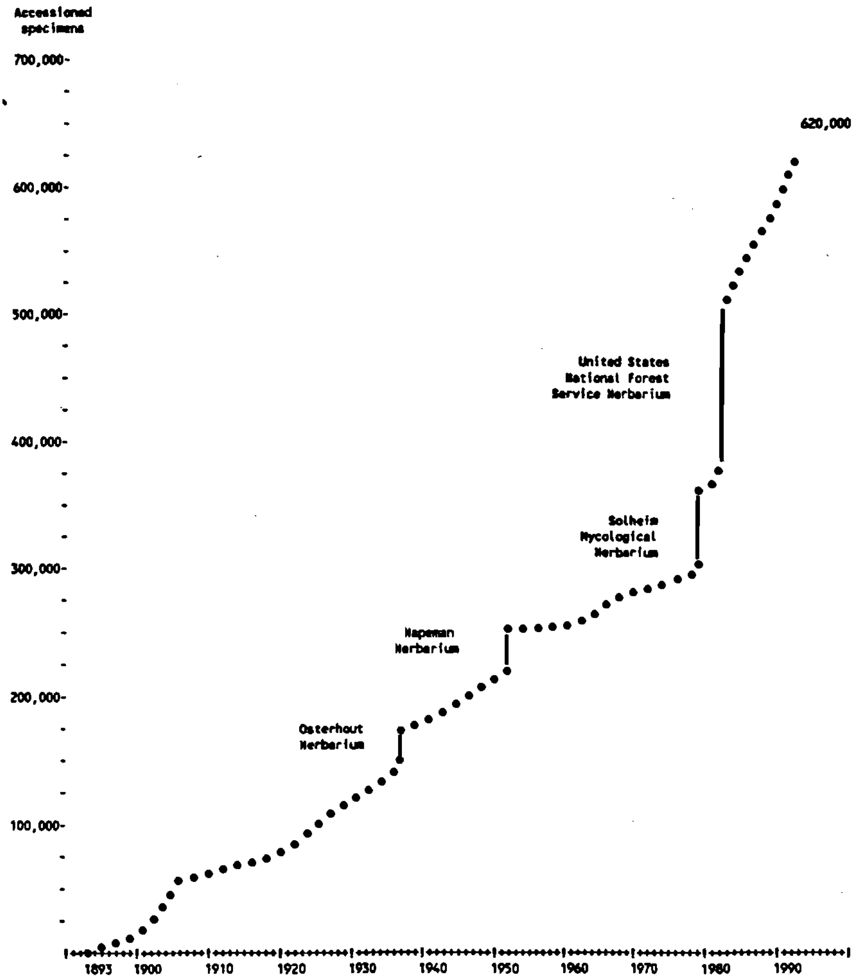

Figure 1. Growth in the number of accessioned specimens since the founding of the Rocky Mountain Herbarium.

Associated with the reference collection are two Wyoming Taxon Checklists (initially compiled in 1979), one of which contains relevant synonymy. Through two cost-share agreements with the national office of the Soil Conservation Service (SCS), a database containing a revised checklist was completed last fall. To each taxon, a literature citation is attached. This has been incorporated into the Plant List of Accepted Nomenclature, Taxonomy, and Symbols (PLANTS) of the SCS. As a consequence of this project, a taxonomic literature database of nearly 3,000 citations pertaining to the flora of Wyoming and the Rockies has been established. This database greatly facilitates plant identification and revisionary work.

A number of steps have been taken to make the processing of new acquisitions as efficient and reliable as possible. The greatest improvement has been in the production of specimen labels, a procedure computerized since 1979 (using the UW mainframe computer). We now use a Zenith 248 with 120 MB hard drive and a Gateway 2000, 486/33C, 8 MB RAM, 500 MB hard drive with a HP LaserJet III printer. We have used three label programs, each of which also captured five categories of data for archiving and eventually databasing. We now use PLabel by Kent D. Perkins (Herbarium, University of Florida) which places all of the data into dBase IV for the Wyoming Specimen Database and produces labels on the LaserJet. A species name dictionary increases both the efficiency and accuracy of data entry. We recently captured data from nearly 14,000 specimens related to a floristic inventory of the west slope of the Wind River Range using this system. We now have a cost-share agreement with the state and national offices of the Bureau of Land Management and the SCS to initiate the capture of specimen label data from the Wyoming sheets in the RM.

Thus far data from more than 80,000 Wyoming collections have been entered into the database. We are also coordinating the project with other groups such as the Specimen Management System for California Herbaria (SMASCH; Tom Duncan), the Intermountain Database Working Group (Mary Barkworth), and the Southeastern Regional Floral Information System (SERFIS; Robert R. Haynes) to establish standards to facilitate the exchange of data.

In 1986, the RM Library was officially recognized as a branch of the UW Libraries. This has greatly facilitated the acquisition of needed taxonomic literature. Also, with the purchase of standard library shelving in 1988, the collection is now consolidated with room for expansion. The RM Library traditionally has been strong in systematic literature for North America. Through the efforts of the previous curator, microfiche editions of many of the important older European works and herbaria were obtained. This microfiche collection continues to grow and includes the herbaria of Candolle, Humboldt, Bonpland and Kunth, Lamarck, Lindley (orchids), Linnaeus, Michaux, Rousseau-Aublet, and Willdenow; the correspondence of Linnaeus; seven botanical journals; selected works of over ninety important 18th and 19th century plant taxonomists (the above from Inter-Documentation Company, the remainder from Meckler Publishing); the type collections of the New York Botanical Garden, the Academy of Natural Sciences of Philadelphia, and the United States National Herbarium; and the Plant Taxonomic Literature Microfiche Collection with over 5,000 titles, most pre-20th Century.

Associated with the Library, but property of the RM, is an extensive reprint collection. It is now housed (tightly) in seven, 4-drawer file cabinets.

The type specimens have been segregated for several decades. The total now stands at over 5,000 (including holotypes, isotypes, lectotypes, and paratypes, categories originally separated by C. L. Porter). The RM Type Register, developed initially by John and Charlotte Reeder and myself (while a M.S. degree student) between 1969 and 1971, lists the types alphabetically by basionym and contains label information and literature citations. It has now been entered into a dBase IV file so that requests for information can be filled quickly and so it can be included in the proposed national database of types.

The RM exchange program has been expanded considerably in recent years and now includes 55 domestic and 15 international institutions. The average number of specimens sent on, and received from, exchange annually has increased from 1,200 and 1,400, respectively, for the period 1962 through 1976 to 3,900 and 3,500 for the period 1977 through 1992. The goal of this program is to obtain representative material, in order of priority, from: the Rocky Mountains, western North America, eastern North America, and arctic, alpine, and temperate regions elsewhere in the Northern Hemisphere. Such programs are extremely important in obtaining material for research from throughout the range of a taxon. Relatively few of the more than 4,300 species in the Rocky Mountains are restricted to the region and many are found throughout much of the Northern Hemisphere. Plant families of special interest (and staff and associates specializing in each) include the Apiaceae (Hartman), Asteraceae (Hartman and G. K. Brown, Associate Professor of Botany), Bromeliaceae (Brown), Caryophyllaceae (Hartman), Cyperaceae and Poaceae (A. A. Beetle, Professor Emeritus of Range Management), and Salicaceae (R. D. Dorn, RM Associate). Dr. Steven L. Miller (Assistant Professor of Botany; mycology) specializes in Basidiomycetes.

An additional method which helps accomplish the above goal is the interinstitutional loan of specimens. At any time, 10,000 to 15,000 sheets from the RM are under study at herbaria and museums throughout the World. Likewise, we borrow thousands of sheets annually for our own research.

Another source of specimens has been gifts, either outright (e.g., private herbaria of Osterhout, Hapeman, and Solheim; R. D. Dorn, Cheyenne) or in exchange for identifying or verifying a set of duplicates (e.g., Bureau of Land Management; National Park Service; U. S. Fish and Wildlife Service; U. S. Forest Service; Wyoming Game and Fish; E. Evert, Park Ridge, IL, Roger L. Williams, Laramie). It is imperative all acquisitions be of high quality and accompanied by adequate data. The last source of specimens for the RM will be covered under the next major heading.

Associated with the RM is a molecular systematics laboratory which was established by Greg Brown and myself. Greg and his students study isozyme variation and restriction fragment length polymorphisms in chloroplast DNA to address evolution in the Bromeliaceae (funded by the National Science Foundation), the Apiaceae, and the Asteraceae.

Housed at the Herbarium is the Wyoming Natural Diversity Data Base (WYNDD) of The Nature Conservancy (TNC). The five full-time employees include a botanist Walter Fertig; (Hollis Marriott, who held this position from 1985 to 1992, is now with the Wyoming Field Office, TNC), two ecologists George Jones, (replacing Hollis as director), and Gillian Walford, a zoologist Chris Garber officed in the Department of Zoology and Physiology, and database manager Mary Neighbours. Our association with this organization has been mutually beneficial in many ways, especially in obtaining cost-share agreements with federal agencies. As the issue of "endangered species" so often cannot be addressed until a careful inventory has been completed, agencies frequently are referred to the Herbarium and the projects are usually done as Master's theses (see below). Data on sensitive taxa collected during a project are then incorporated in WYNDD or similar databases in other states in which we do inventories. We also serve in an advisory roll as to what plant taxa, and rank, should be included in lists of special concern for Wyoming and Colorado.

The Curator chaired a committee on the implementation of a geographic information system for research at UW. Initial funding has enabled the establishment of four nodes (Botany, Geography and Recreation, Geology and Geophysics, and Zoology and Physiology) on the campus ethernet. Housed in the Herbarium is a Sun SPARCstation 2 with 16 MB RAM, 414 MB of storage, a Calcomp 36 X 48" digitizer, ARC/INFO and GRASS software, and access to a 36", eight-pen plotter, a 6.6 GB read/write optical disk jukebox, a tape backup, and a CD reader. Recent additions to the GIS network include five Sun SPARCstations (2 Botany—Ecology, 1 Geography, 2 Wyoming Water Center [WWC]), a Sun file server [WWC], a Howtek Scanner, 1,200 dpi, 12 x 18" (Geography), and a 55 GB optical disk jukebox with two drives [WWC]. Since nearly all of these items were purchased with matching funds from the state, they are available within reason for use by all on the system.

In order to provide instruction in the applications of computers to field and museum research, William J. Gribb (Geography) and I have just received NSF funding ($124,000 including UW match) to establish the Digital Earth Sciences Laboratory (primarily for Botany, Geography and Recreation, Geology and Geophysics, Plant, Soil, and Insect Sciences, Range Management, and Zoology and Physiology). It will have ten PCs (486/66 EISA with 500 MB drives), a 35 mm film color scanner, a color printer, an 8 mm video camcorder, a Global Positioning System community base station (to be housed under cooperative agreement at the Casper BLM office for use by UW and federal agencies in differential GPS throughout Wyoming), a 6-channel field GPS with barcode data logger, three GPS units for recording waystations, a micro-meterological station with datalogger, 2 digital image projectors, an audio-to-digital converter, and software (dBase IV, SPSS-PC, PC/ARC/INFO, MIPS, ERDAS, GRASS, Geo-Link, Delta Classification System, Pankey, Tropicos, Mecca, ImageQuery, etc.). It will also house part of the GIS research network mentioned above and have access to other hardware and software on the network. This facility will be used in a number of courses and for various purposes. In addition to its use for teaching GIS, GPS, and remote sensing, other applications for undergraduate and graduate courses in plant systematics include the use of available software for generating multiple-access keys, dichotomous keys, parallel descriptions, the databasing of label data for monographic work, etc.

As a member of the Wyoming GIS Steering Committee, the Wyoming GIS Users Group, and the State Mapping Advisory Committee, and through contact with the Rocky Mountain Mapping Center of the U.S. Geological Survey, Denver, I am interacting with state and federal agencies to assist in the building of a state GIS with a minimum duplication of effort. For example, computerized data in the RM will serve as a layer on species distributions, and the mapping of plant communities in Wyoming and Colorado through remote sensing (William A. Reiners and associates, Botany) will provide other layers. Data from the former will help in the "ground" truthing of the vegetation maps.

RECENT FLORISTIC INVENTORIES IN THE ROCKY MOUNTAINS

As mentioned above, in 1978 we initiated an intensive and systematic floristic inventory of Wyoming and other Rocky Mountain states with the following goals: 1) document the flora of the Rockies; 2) determine taxa truly in need of protection (many candidates for status as Endangered or Threatened, as well as the recent novelties, have proven to be relatively common although often restricted in habitat); 3) provide data for the Flora of North America project (the Curator is a regional coordinator), and for regional (the Curator is a member of the Great Plains Flora Association; Hartman 1986a, 1986b, 1986c), state (we share data freely with Dorn for revisions of ***Vascular Plants of Wyoming***) and local floras; 4) provide data for monographic and revisionary studies and for research in plant geography; and 5) computerize data from specimen labels.

During 12 of the past 15 summers, this inventory by the RM staff, graduate students, and associates (Dorn, Evert, Williams, WYNDD, etc.) has amassed 192,000 numbered collections, not including duplicates for exchange. While many have been talking about a National Biological Survey, we have accomplished a great deal towards that end for many areas in the Rockies with relatively little funding. Such inventories provide a wealth of information on the geographical and ecological distribution of native species as well as introductions, which often have great economic impact on agriculture (the Herbarium Manager is coauthor of ***Weeds of the West***, Whitson et al. 1991). Representative material collected in a systematic manner also documents morphological variation or, of equal importance, uniformity throughout this portion of the geographical range of each species. Thus, floristic work is invaluable in obtaining research material for monographers who might otherwise be unable to acquire samples from remote and often roadless areas. It also provides excellent taxonomic training at the master's degree level prior to specialization in a doctoral program or employment in areas of natural resource management (e.g., as botanists with Natural Heritage Programs and state and federal agencies).

The various floristic inventories which have been conducted in recent years, and one which is anticipated, through the RM are discussed below (Fig. 2). But first I will cover methodology.

During the first summer of a thesis project, Ernie and I alternate working with the student during three, sometimes four, two-week periods. This insures that our standards, as well as continuity with previous studies, are maintained. During the second field season, each of us may spend one two-week period with the student. Some of the projects have not been associated with Masters thesis, but have been done solely by Ernie and myself.

Three things we request when doing an inventory are work space, access to a freezer for ice (made in one-gallon plastic milk jugs), and access to a shower. Because of the scale of the projects, it is imperative that we have a work center for the pressing and drying of specimens. We have been fortunate in nearly all of our studies to have had space and electricity supplied by state or Federal agencies (UW Agricultural Extension Service, U. S. Forest Service, Bureau of Land Management, National Park Service, etc.).

In topographic basins, our general mode of operation is to choose an area which has not been surveyed. We drive to the site and collect all taxa of vascular plants encountered in flower and/or fruit, covering as many plant communities as possible, and often hiking several miles. Over the next ten miles, we look for new and diverse habitats, often stopping one to three times, to obtain material of species not collected at the first or subsequent sites. We then repeat the process over the next ten-mile segment of road, or one elsewhere in the basin. In part, the goal is to sample at frequent intervals in order to capture the diversity of taxa in the project area. But more so, we attempt to document morphological variation, or lack thereof, and ecological and geographical distribution at a relatively fine scale. The samples are placed in plastic bags by location and habitat, stored on ice, and field data are recorded. Upon return to the work center (often late at night), the worker(s) showers, gets a good nights sleep (usually in personal vehicles), and then spends the next day pressing the material, again often late into the night. Of utmost importance is placing the plants into the ice chest (100 quart capacity) within a reasonable period of time. In montane areas, it is sufficiently cool to keep plant material fresh, stored in a backpack, for most of the day.

In mountainous regions (due to greater diversity, to being on foot with backpack, and to the significant elevational relief), the interval for repeating the collecting cycle is about five miles and often there are many more stops along the way. Following each trip, the route traveled and date are marked on a U. S. Geological Survey, 7.5 minute sheet as well as a small-scale map of the area. The latter helps in planning trips as the season progresses.

Collecting tools have varied, but due to the hard and rocky substrates frequently encountered we mostly use a bricklayer's hammer with its chisel end. In the alpine we may employ a sturdy screw driver or a pocket knife.

Our plant driers have become more streamlined through the years but basically consist of a box 6' long, 20" wide, and 24" high built from 1/4" plywood. Two small door hinges, with removable pins, on each inside corner make it collapsible. Vent holes (1-1/4" in diameter) along the bottom on each side allow for the circulation of air. A frame covered with screen 1/4" mesh) at 20" above the floor prevents debris from falling into the box. Five sockets with 150 watt incandescent bulbs spaced along the floor provide the heat. End boards for plant presses are cut from 1/4" plywood; straps from 1/4 or 3/8" cotton sash cord (16.7' long; each with a loop tied at one end). Double-faced corrugates are purchased commercially.

Generally the collecting/drying cycle is 48 hr. Plants obtained one day are placed on the drier the next and remain there for about 36 hr. In our arid climate, most species dry within one cycle. What is not dry (e.g., conifers for which cones are stored separately in small paper bags numbered correspondingly; cacti and other succulents) is returned to the press. The

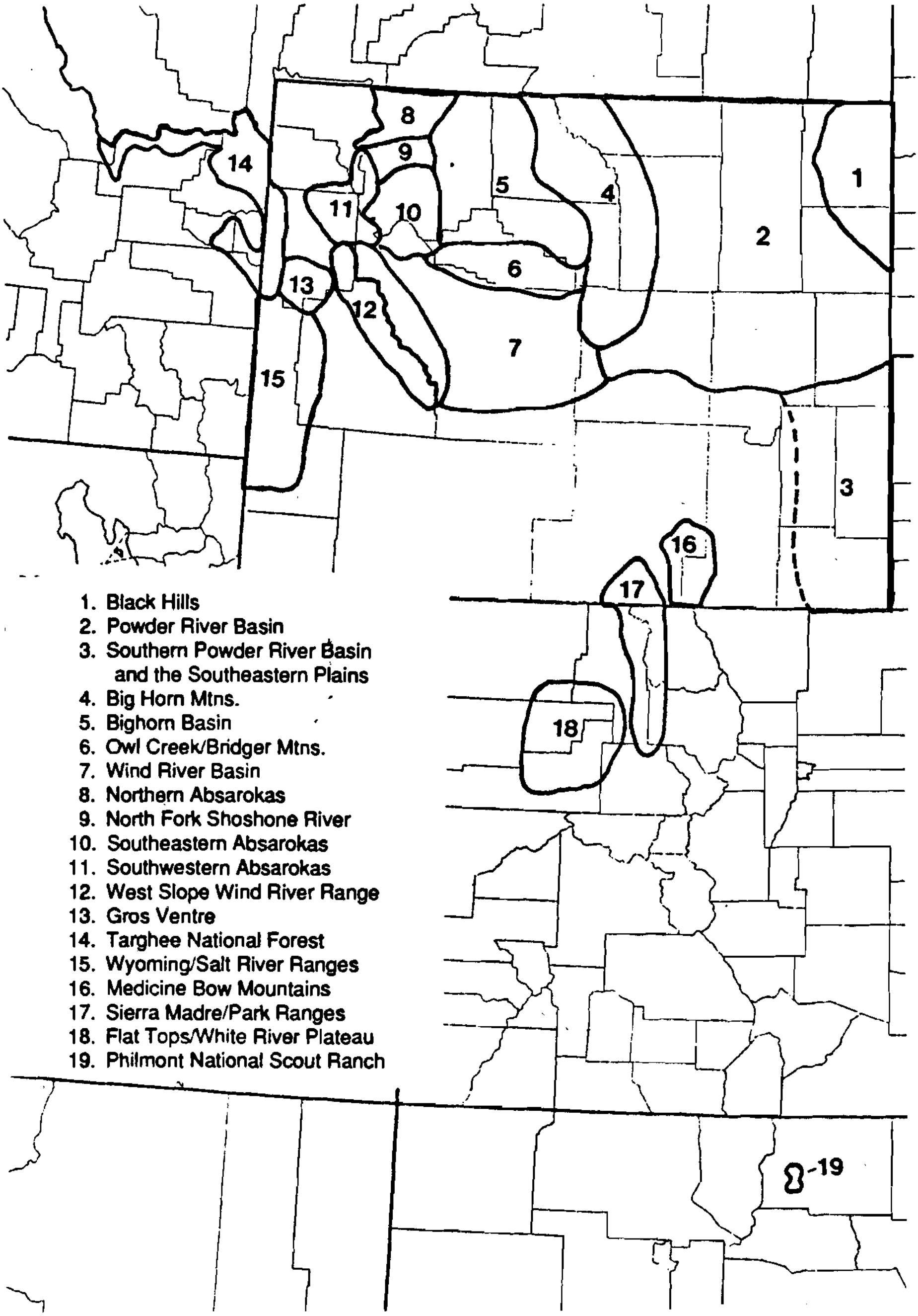

Figure 2. Recent areas of inventory by staff, students, and associates of the Rocky Mountain Herbarium. Coverage of area 3, Southern Powder River Basin and the Southeastern Plains, is planned for the summers of 1993 and 1994.

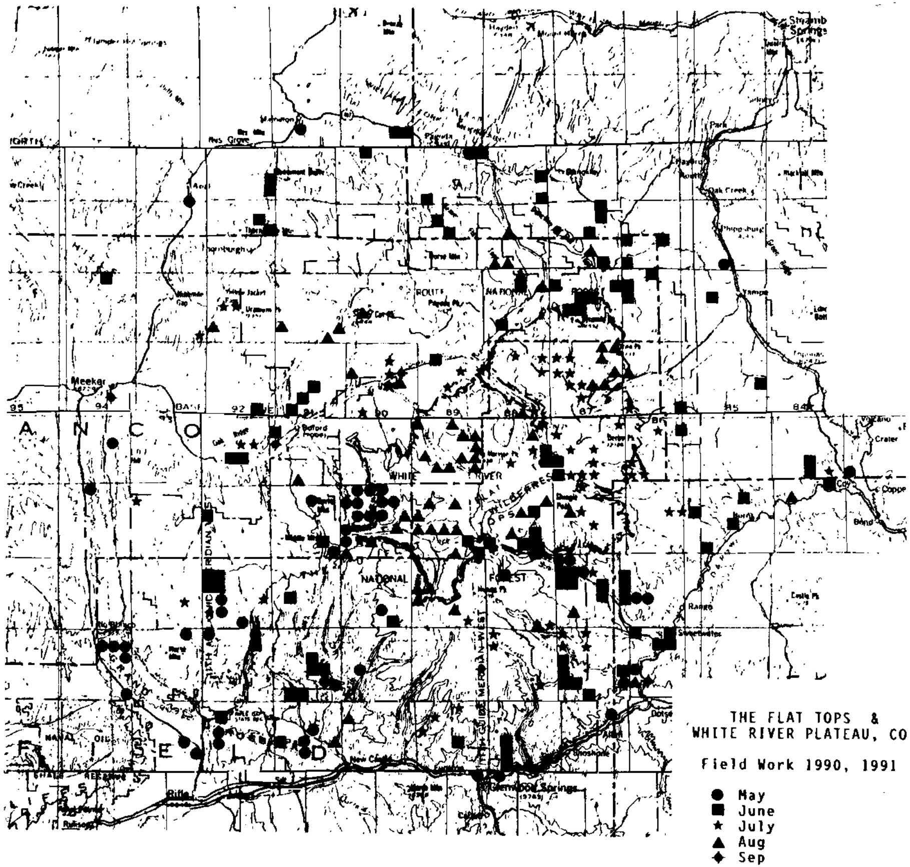

Figure 3. Flat Tops, the White River Plateau, and vicinity (Colorado) study area with different symbols indicating month of collection for each site.

dried plants in newspaper are placed in 6-8" stacks between two corrugates and tied with heavy string. They are stacked for eventual transport to the RM. Upon concluding a study, a map showing the collecting locations (e.g., Fig. 3), often a list of sites (by township, range, and section), and a species checklist are prepared and made available to individuals, often speciality collectors, interested in doing further fieldwork.

When working on federal lands, a set of specimens containing one of each taxon, for which we have a duplicate, is given to the agency for a reference collection. These are supplied in newspaper with labels, although we will mount them if funding for supplies and labor is provided. Also, material from a project area is made available through our exchange program to appropriate colleges and universities in the area (e.g., when collecting in Colorado, we exchange with COLO, COCO, CS, and Mesa College, Grand Junction, the last too small [4,000 specimens] to be included in Holmgren et al. 1990).

Except for our first project (Powder River Basin), funding has been low and often from several sources. These include contributions from individuals (the late Louis O. Williams and his wife Terua, J. Vickers Brown, Roger L. Williams, R. L. Hartman, Orval C. Harrison, John F. Freeman, Ron Schreibeis, Jean Oxley, and Brenda Schladweiler), small grants and scholarships (The Nature Conservancy, the Colorado Natural Heritage Program, Colorado Native Plant Society, Wyoming Native Plant Society, Paul Stock Scholarship, Payson Scholarship, Devils Tower Natural History Association, the U. S. Forest Service, and the Bureau of Land Management), and donation of time and resources by graduate students, staff, and associates. We feel fortunate to raise $2,500 to $3,000 for a student per summer to cover gas and food (as mentioned above, we sleep in our own vehicles although the Forest Service occasionally has provided a cabin or house trailer).

Black Hills (Wyoming; Fig. 2, area 1)

The Black Hills have long been of interest to botanists (Dorn 1977b), but much of the work has centered in the South Dakota portion (two-thirds of the area). The Wyoming segment covers 2,500 mi^2 and includes the Bear Lodge Mountains (Warren Peaks, 6,600 ft), Devil's Tower, and portions of the Hogback Rim, Red Valley, Minnelusa Foothills, and the Limestone Plateau. The floristic affinities lie largely with the Rocky Mountains and, to a lesser extent, the Great Plains. During 1983 and 1984, over 12,000 collections (an average of 4.8 specimens/mi^2) were obtained. The documented flora is now 955 taxa, an increase of 66%. This number includes 14 additions to the vascular flora of Wyoming and 62 new or clarified records for the Black Hills as a whole (Hartman and Marriott 1980, Marriott 1985, 1986).

Powder River Basin (Wyoming; Fig. 2, area 2)

Located in northeastern Wyoming, the Basin is defined as the region underlain by vast coal deposits of Tertiary and Upper Cretaceous age. The areal extent is nearly 18,000 mi^2, equivalent in size to Vermont and Massachusetts. This region, which has undergone rapid energy development, had been little known floristically. Approximately 12,500 collections (0.7/mi^2) were obtain during 1978 and 1979, thanks to funding by the Rocky Mountain Institute of Energy and Environment, UW. Of the 900 taxa of vascular plants documented, 281 were reported as new to the Basin (a 31% increase). Furthermore, eleven species were found to be new to the flora of Wyoming. These data were provided to the Flora of the Great Plains project. The region contains largely a mixture of Great Plains and Great Basin elements with scattered islands of species on buttes (especially the Pumpkin Buttes) and ridges having a montane affinity (Dueholm and Hartman 1981, Hartman and Dueholm 1979a, 1979b, Hartman, Dueholm, and Nelson 1985, Hartman et al. 1980).

Southern Powder River Basin/Southeastern Plains (Fig. 2, area 3)

Although the Powder River Basin (PRB) was inventoried in the late 1970s, the southern portion needs additional work. The Rawlins District of the Bureau of Land Management is funding a project covering the northern 60-70% of Natrona and Converse counties and all of Niobrara County (PRB) as well as Platte and Goshen counties (southeastern plains). We will also include Laramie County (plains) in this thesis area. The fieldwork will be done in 1993 and 1994.

Big Horn Mountains (Fig. 2, area 4)

This crescent-shaped range (3,600 mi²) has a maximum elevation of 13,175 ft (Cloud Peak). To the northwest it is isolated from the Pryor Mountains (Montana) by the Big Horn Canyon, while to the southwest a depression separates it from the Bridger Mountains. Knowledge of the flora has accumulated over the years through the efforts of numerous collectors. Nevertheless, vast areas of the Big Horns have remained unexplored botanically. During 1979 and 1980, in excess of 8,000 collections (2.2/mi²) were obtained which, along with earlier accessions at RM, provide a fairly detailed coverage. Over 1,100 taxa are now documented from the Big Horns, an increase of 46% (Nelson and Hartman 1983, 1984). Four species, *Aquilegia jonesii* Parry, *Erigeron allocotus* Blake, *Penstemon caryi* Pennell, and *Sullivantia hapemanii* (Coult. and Fish.) Coult., previously considered rare were found to be fairly common although often restricted to specific substrates. Of special relevance is limestone and dolomite which constitute a large proportion of the sedimentary strata. *Cymopterus williamsii* Hartman and Constance (1985), a previously undescribed taxon, was found throughout the southern half of the range.

Bighorn Basin (Fig. 2, area 5)

The Basin covers 7,300 mi², ranging in elevation from 3,640 to 7,000 ft (8,123 ft on Heart Mountain). Very little floristic work had been done prior to this decade. Since 1980, more than 9,000 collections (1.2/mi²) have been obtained. Interestingly, many of the taxa in common with the Powder River Basin bloom up to one month earlier in the Bighorn Basin, presumably due to the early onset of summer drought. The known flora now stands at 687 taxa, an increase of 108%. During this period, the following taxa were described from the area as new to science: *Astragalus jejunus* Wats. var. *articulatus* Dorn (1988) and (see discussions below) *Antennaria aromatica, Cymopterus evertii, Lomatium attenuatum*, and *Shoshonea pulvinata*. An additional novelty in *Cymopterus* remains to be described (Hartman 1987). The following sensitive species were also found: *Eriogonum brevicaule* Nutt. var. *canum* (Stokes) Dorn, *Kelseya uniflora* (Wats.) Rydb., *Rorippa calycina* (Engelm.) Rydb., *Stanleya tomentosa* Parry, *Sullivantia hapemanii, Townsendia nuttallii* Dorn, and *T. spathulata* Nutt. (Nelson and Hartman 1990).

Owl Creek/Bridger Mountains (Fig. 2, area 6)

An inventory began, primarily in 1991 on these east-west trending ranges (1,800 mi²), approximately half of which is on the Wind River Indian Reservation. The relief varies from 5,000 to 9,684 ft (Phlox Mountain) in the Owl Creeks and to 8,272 ft (Copper Mountain) in the Bridgers. The two are bisected by the Wind River Canyon with a depth of up to 2,240 ft. Being relatively dry and composed largely of limestone and other sedimentary strata, this area is of special interest as a potential refuge of novelties. Furthermore, these ranges may have served as a migratory route between the Absarokas and the Big Horns. About 2,000 specimens have been obtained (by W. Fertig, Hartman, R. Jones, H. Marriott, and Nelson; 1.1/mi²) but much work remains to be done, especially on the Reservation. Thus far only a small portion of the material has been identified. Species of note include *Cryptantha subcapitata, Shoshonea pulvinata*, and *Townsendia nuttallii* (see discussions below).

Wind River Basin (Fig. 2, area 7)

This Basin, excluding the Wind River Indian Reservation, was covered during 1985 and 1986 (Haines 1988), although some work was also done by June Haines in the late 1970s and early 1980s. Specimens from the earlier period are deposited at Central Wyoming College, Riverton. Prominent features of this xeric basin include Beaver Rim, Gas Hills, Rattlesnake Hills, and the Granite Mountains. Except for the last area, much of it is composed of shales, mudstones, sandstones, and derivatives. A total of 6,600 collections have been obtained from this 5,000 mi² area (1.3/mi²). Despite severe drought conditions during the thesis study, 885 taxa (including previous holdings in RM) were documented (79% increase). Over 214 first county records were obtained. Further work is needed during years of favorable growth. Recently described taxa from the Basin, some of which were collected in the course of the inventory, include: *Cryptantha subcapitata* Dorn and Lichvar (1981a), *Phlox pungens* Dorn (1988), *Physaria eburniflora* Rollins (1981), *P. saximontana* Rollins (1984), *Trifolium barnebyi* (Isely) Dorn and Lichvar (1981b; originally as *T. haydenii* Porter var. *barnebyi* Isely 1980), *Cirsum* sp. (Dorn, unpubl.), and *Yermo xanthocephalus* Dorn (1991). The last genus was new to science.

Northern Absarokas (Fig. 2, area 8)

The Absarokas were divided into four study areas: the Northern, the Southeastern, the Southwestern, and also the North Fork of the Shoshone River Drainage. The range is composed predominantly of volcaniclastics, largely andesite, and is one of the most rugged in North America (Fenneman 1931). Along the eastern margin, sedimentary strata, especially limestone, are exposed.

During 1985 and parts of 1988 and 1989, 6,500 collections were made throughout the Northern Absarokas (900 mi²; 7.2/mi²). This study was prompted by a visit in 1984 of the Wyoming Native Plant Society led by E. F. Evert to the calcareous bog at the base of Cathedral Cliffs near Crandall Ranger Station. During a four hour reconnaissance, nine species new to Wyoming were encountered, one of which was new to the conterminous United States (Evert et al. 1986). Some additional records were discovered in subsequent years (Snow, Nelson, and Hartman 1990) and a total of 748 taxa were documented, but the bog remains unique in the state in the number of unreported taxa it harbored. Prominent features include alpine expanses such as Hurricane Mesa (11,010 ft), Trout Peak (12,244 ft), Black Mountain (11,562 ft), Dead Indian Mountain (12,216 ft), and the divide along the eastern border of Yellowstone National Park. As much of the area is roadless and remote, at least one more summer will be needed to complete the inventory.

North Fork Shoshone River Drainage (Fig. 2, area 9)

This drainage arises near the east entrance of Yellowstone National Park and separates the Northern from the Southeastern and Southwestern Absarokas. Erwin F. Evert has been seriously inventorying the area since about 1978. It is undoubtedly the most thoroughly studied area in the state with more than 12,000 collections from 800 mi² (15/mi²). Approximately 1,070 taxa have been documented representing an increase of over 500% in the known flora (Evert 1982, 1991, Evert and Hartman 1984). Included are more than 24 species new to Wyoming and the following taxa which were new to science: *Antennaria aromatica* Evert (1984a), *Carex luzulina* Olney var. *atropurpurea* Dorn (1988), *Lomatium attenuatum* Evert (1983), *Penstemon absarokensis* Evert (1984b), and *Shoshonea pulvinata* Evert and Constance (1982). The last genus also was new to science.

Southeastern Absarokas (Fig. 2, area 10)

This portion of the highly dissected volcanic plateau ranges in elevation from 7,500 to 13,148 ft (Francs Peak). During 1983 and 1984, over 10,500 collections were obtained in this essentially roadless area of 1,700 mi² (6.2/mi²). Over 915 taxa were documented representing an increase in the known flora of 231% (Kirkpatrick 1987). Although *Cymopterus evertii* Hartman and Kirkpatrick (1986) was first encountered on a small sandstone ridge at 5,800 to 6,000 ft in the Bighorn Basin, it was found to be common on pyroclastic andesites at

8,600 to 10,800 ft in the vicinity of Carter and Phelps mountains. Other novelties encountered include: *Ipomopsis spicata* (Nutt.) V. Grant ssp. *robruthii* Wilken and Hartman (named in honor of Rob and Ruth Kirkpatrick; also found in the Northern Absarokas; Wilken and Hartman 1991), a new variety of *Silene kingii* (Wats.) Bocq. (Hartman and Dorn, unpubl. manuscript), and an undescribed species of *Cymopterus* (mentioned under Bighorn Basin). *Astragalus gilviflorus* Sheld. var. *purpureus* Dorn (1988) was characterized from the extreme southern edge of the area.

Southwestern Absarokas (Fig. 2, area 11)

It is separated from the Southeastern Absarokas by the South Fork of the Shoshone River and Shoshone Pass on the north and the East Fork of DuNoir Creek on the south. Much of the area forms the headwaters of the Yellowstone River; it is roadless and includes the most remote portions of Wyoming (up to a 25 mi^2 hike through prime grizzly bear country to the furthermost point). From this study area of 1,500 mi, over 5,600 collections were obtained (3.7/mi^2) during the summers of 1987 and 1988. A total of 891 taxa were documented from an area virtually unbotanized previously. Although no novelties nor state records were encountered, first records for the following counties were obtained: Teton, 56; Fremont, 22; and Park, 36 (Snow 1989, 1990, Snow, Nelson, and Hartman 1990). *Descurainia torulosa* Rollins (1983) had been described from the southern edge of the area. Much additional work is needed in the alpine (Trident, Thorofare, and Buffalo plateaus and Yellow Mountain).

West Slope Wind River Range (Fig. 2, area 12)

During the summers of 1990 and 1991, through a cost-share agreement with the Bridger-Teton National Forest, this area was inventoried. It extends from Togwotee Pass southeast along the Continental Divide to South Pass and ranges in elevation from 7,500 to 13,700 ft. The areal extent is 1,700 mi^2. The northern portion is sedimentary with some volcanics, whereas the southern part is primarily Precambrian in origin. More than 13,800 collections were obtained (8.1/mi^2) and the total flora now stands at 1,033 taxa (58% increase). Thirty-seven sensitive species of vascular plants (WYNDD and U. S. Forest Service lists) were documented. Many of these are restricted to exposed limestone on the mountains adjacent to the Green River Lakes. Four species new to the flora of Wyoming were also discovered (Fertig, Hartman, and Nelson 1991, Fertig 1992a, 1992b, Hartman, Nelson, and Fertig 1991).

The alpine of the eastern slope of the Wind River Range was inventoried by Richard W. Scott during 1963, 1964, and 1965 (Scott 1966). He returned to Wyoming in the mid-1970s to teach at Central Wyoming College (CWC) and continues his inventory of the east flank of the Wind River Range and adjacent areas in preparation for publishing an alpine flora of Wyoming and adjacent areas. The RM maintains an active exchange program with CWC (herbarium not in Holmgren et al. 1990; contains 22,000 accessions).

Gros Ventre (Fig. 2, area 13)

During the summer of 1977 (prior to my arrival) and to a limited extent in 1978, roughly 1,600 collections were obtained from this area (960 mi^2; 1.7/mi^2). A total of 959 taxa were documented, increasing the known flora by 51% (Lichvar 1979a). Included in this list is *Draba borealis* DC., a boreal species previously known in the conterminous United States only from Colorado (Lichvar 1979b). Furthermore, 125 additions to the vascular flora of Teton County were encountered in the course of perusing the RM and during the fieldwork (ones not covered by Shaw 1976; Hartman and Lichvar 1980).

Targhee National Forest (Wyoming and Idaho; Fig. 2, area 14)

Fieldwork was conducted in 1991 and 1992 with funding provided by the Forest Service via The Nature Conservancy. The first season focused on the Snake River Range, the Big

Hole Mountains, and the west slope of the Teton Range (1,260 mi^2). The second covered the remainder of the Forest and adjacent areas including: Beaverhead Range, Centennial Range, Henry Lake Mountains, and Island Park area (1,620 mi^2). In 1991, 8,701 specimens (6.9/mi^2) representing 765 taxa were obtained including seven species of special concern to the Forest (Markow 1992). This past summer, a drought year, 5,063 specimens (3.1/mi^2) were collected and currently are being identified.

Wyoming/Salt River Ranges (Fig. 2, area 15)

The Willow Creek drainage (150 mi^2) in the northern Wyoming Range, was inventoried in 1990 through a cost-share agreement with Bridger-Teton National Forest. A total of 1,821 collections were obtained (12/mi^2) and the number of taxa documented was 532 including four of special concern (WYNDD; Hartman, Nelson, and Fertig 1991). Under a similar agreement, the remainder of the northern portion of the ranges was inventoried in 1992 (1,440 mi^2). A total of 7,776 collections were acquired by B. Embury, W. Fertig, Hartman, and Nelson (5.4/mi^2). The southern portion will be inventoried in 1993. The ranges are part of the overthrust belt which extends along the western edge of Wyoming and are composed solely of sedimentary materials, especially limestone. In recent years, several taxa new to science have been described from here including: *Astragalus shultziorum* Barneby (1981), *Physaria dornii* Lichvar (1983), *P. integrifolia* (Rollins) Lichvar var. *monticola* Lichvar (1984). Species of special concern found to be relatively abundant, often in scattered areas, are *Astragalus paysonii* (Rydb.) Barneby, *A. shultziorum Barneby*, *Lesquerella paysonii* Rollins, and *Lomatium bicolor* (S. Wats.) Coult. & Rose var. *bicolor*, whereas *Draba borealis* was encountered only twice.

Medicine Bow Range (including the Snowys; Fig. 2, area 16)

This area, located about 30 mi west of Laramie, has undergone intensive collecting by A. Nelson, C. L. Porter, and others and has been the site of many ecological studies by W. D. Billings, L. C. Bliss, R. F. Daubenmire, D. H. Knight, H. A. Mooney, and their students. For nearly 50 years, the S. H. Knight Science Camp (UW) served as the base for teaching field taxonomy and ecology courses. During the summer of 1973, B. Ernie Nelson collected about 1,000 numbers to supplement those already in the RM. These served as the basis of his M.S. thesis which contained dichotomous keys to the plants of the area. Historically, fieldwork has been concentrated along the highway traversing the range. In recent years, attempts have been made to inventory other areas including Sheep, Elk, Sheephead, and Jelm mountains, Kennedy Peak, and North Gate Canyon (Dorn, Hammel, Hartman, Nelson). A revised edition of the flora (Nelson 1984) containing 867 species of vascular plants has incorporated much of the new data and the inventory will continue as time permits.

Sierra Madre/Park Ranges (Wyoming and Colorado; Fig. 2, area 17)

This area, covering 2,200 mi^2, was inventoried during 1988, 1989, and 1990. Funding was obtained in part from the Routt National Forest and the Wyoming Native Plant Society. It ranges in elevation from 6,800 to 11,007 ft (Bridger Peak) in the Sierra Madre and to 12,180 ft (Mount Zirkel) in the Park Range. Composed of sedimentary strata along portions of the flanks, both ranges have a large, exposed core of Precambrian gneisses, schists, granites, quartz, etc. Also, volcanic activity has occurred in areas of the Park Range. A total of 5,290 collections (2.4/mi^2) representing 825 taxa were obtained. One new record for Wyoming (*Ipomopsis aggregata* [Pursh] V. Grant ssp. weberi Grant and Wilken) and 13 sensitive species for Colorado and/or Wyoming were documented (Kastning 1990).

Flat Tops/White River Plateau (Colorado; Fig. 2, area 18)

This inventory, conducted during 1990 and 1991, was funded in part by White River National Forest, The Nature Conservancy, and the Colorado Native Plant Society. The study area (Fig. 3) included all of the Flat Tops (Little, Dunkley, and Beaver; volcanic plateaus), the White River Plateau, parts of the Yampa, Williams Fork, White, and Colorado river valleys, and most of the Grand Hogback (2,500 mi²). It ranges in elevation from 5,300 ft near Rifle to 12,245 on Sheep mountains. Approximately 6,500 collections (2.6 mi²) representing 852 vascular plant taxa were obtained. A total of 27 populations of 11 species of special concern were located; 20 of the populations were newly discovered; seven of the taxa previously had not been reported from the study area. All but one of these taxa occurred in the southern 40% of the range, the portion composed largely of limestone (Vanderhorst 1992).

Philmont National Scout Ranch (New Mexico; Fig. 2, area 19)

During 1968 about 1,290 collections were obtained from this 210 mi² area in the Sangre de Cristos. Over 760 taxa were documented including 11 new to the state (Hartman 1973) and two new to science: *Eriogonum aliquantum* Reveal (1976) and *Heuchera hallii* A. Gray var. novum (Hartman, unpublished). In 1991, Bruce Embury obtained an additional 500 numbers (average now 9/mi²) in preparation for a floristic inventory of a larger area in north-central New Mexico (Raton west to Costilla and southwest to Ocate and Taos; western Colfax, eastern Taos, and northwestern Mora counties; 2,500 mi²).

The next decade or more of fieldwork at RM will focus on completing the inventory in Wyoming, southeastern Idaho, the west slope of Colorado, and the north-central 20% of New Mexico. The last area undoubtedly is the most poorly known botanically. We will coordinate efforts with botanists in these neighboring states to minimize duplication of effort. Because of limited resources, I do not foresee much fieldwork above the 45 parallel (Wyoming's northern border) in the near future. Our hope is to encourage botanists in Montana, Idaho, Alberta, and British Columbia to cover those states and provinces. Utah botanists, especially those associated with Brigham Young University (Stanley Welsh, students, and associates), are doing an admirable job of covering their state. Likewise, workers in the Great Plains, especially H. A. "Steve" Stephens and Ralph Brooks, have made a fairly good effort of inventoring the Black Hills of South Dakota (ca. 10,000 numbers). Unfortunately, the eastern plains of Colorado and Montana desperately are in need of detailed inventories.

What have we and others involved in similar projects in Wyoming accomplished during the past 15 years? A total of 306 new state records have been documented (Table I) and forty-six taxa new to science have been described (at least five more will be published soon)! Forty-one "resurrected" taxa (ones previously considered synonyms of other species but now recognized) have been added. Finally, 32 reports of taxa have been confirmed (with specimens to document the literature reports). The grand total is 425 taxa! Comparing only the number of species new to Wyoming with the number in Dorn (1977a; he did not include infraspecific taxa), there was an increase of 15.8% or one in every six species was new! Of the total number of taxa new to Wyoming, only 24% are introduced (Hartman and Nelson unpubl.). Several of these represent potential agricultural pests.

From 1974 through 1990, 142 taxa new to science have been described from the Rocky Mountains (United States) compared with 174 from the Intermountain Region, 163 from California, 121 from the Southwest, 92 from the Southeast, 45 from the Northwest, 39 from the Northeast, and 14 from the Great Plains (Table II; subtotals, therefore, not including named hybrids nor formas). Based on these data (Hartman and Nelson unpubl.), it is apparent that the Rocky Mountains continue to warrant considerable floristic study. Despite this fact, there is a real need to begin the publishing of taxonomic treatments for the region.

Table I. New Wyoming plant records since Dorn (1977a).

	Species	Subspecies	Varieties	TOTAL
New Record	258	4	44	306
New to Science	36	3	7	46
Resurrected Taxa	17	1	23	41
Reports Confirmed	28	0	3	32
	New Wyoming Plant Records		GRAND TOTAL	425
Introduced taxa	98	0	5	103
from above list = 24% of New Wyoming Records				

Table II. Number of taxa by category described from various regions of the conterminous United States and from California during the past 16 years.

Region	Species	Subsp.	Var.	Subtotal	Form	Hybrids	Total
Northeast	25	4	10	39	5	16	60
Southeast	58	9	25	92	24	11	127
Great Plains	7	1	6	14	4	1	19
Southwest	72	15	34	121	5	2	128
Rocky Mtns.	85	13	44	142	3	1	146
Intermtn.	100	9	65	174	1	0	175
Northwest	27	6	12	45	2	0	47
California	73	50	40	163	1	3	167

FLORA OF THE ROCKY MOUNTAINS PROJECT

The only two regional floras are Coulter and Nelson's ***New Manual of Botany of the Central Rocky Mountains (Vascular Plants)*** published in 1909 (covering Colorado, Wyoming, most of Montana, the Black Hills of South Dakota, southern Idaho, the eastern half of Utah, the northern half of New Mexico, and adjacent Arizona) and Rydberg's ***Flora of the Rocky Mountains and Adjacent Plains: Colorado, Utah, Wyoming, Idaho, Montana, Saskatchewan, Alberta, and Neighboring Parts of Nebraska, South Dakota, North Dakota, and British Columbia*** published in 1917. The former was a new book, written by Nelson to replace John M. Coulter's earlier work (1885), but the latter was given senior authorship (Williams 1984). It was a relatively conservative treatment for the time and thus quite popular. Rydberg's Flora covered a much larger area, but extensive splitting at the species level greatly decreased its utility. Obviously, both are now obsolete except for historical purposes. Weber's ***Rocky Mountain Flora (1967*** and revision) is a misnomer representing little more than revision of his extremely useful ***Handbook of the Plants of the Colorado Front Range*** (1953 and revisions); it is of limited use beyond the Colorado Rockies.

The current project (Hartman 1990a, 1990b) was initiated with a symposium entitled The Flora of the Rocky Mountain Region (RMR) held at the Southwestern and Rocky Mountain Division of the American Association for the Advancement of Science Meeting in Colorado Springs, May of 1990. Speakers were Jane M. Beiswenger, Paleofloristics (Quaternary) of the RMR; Stanley A. Morain, Origin and evolution of the Rocky Mountain flora; William A. Weber, Phytogeographical affinities between the Rocky Mountains and Asia; William H. Moir, Vegetation zones and plant communities of the RMR; Theodore M. Barkley, The success of the Flora of the Great Plains Project; Stanley L. Welsh, The success of the Utah Flora Project; and R.L. Hartman, Floristic inventories and the Flora of the Rocky Mountian Project. Many of these authors will be contributing chapters to the Introduction for the Flora. Other contributors include Brainerd Mears, Jr., Physiography and geomorphology of the RMR;

Roger L. Williams, Botanical exploration of the RMR; S.A. Morain, Plant geography and floristic divisions of the RMR; and R.L. Hartman, Endemism in the RMR.

The Flora of the Rocky Mountains: Vascular Plants of the Rocky Mountains and Adjacent Plains and Basins, North America will consist of five or six volumes with a format similar to that of the ***Intermountain Flora*** (Cronquist et al. 1972 and subsequent ones) although certain modifications will be adopted from Flora of North America (FNA Editoral Committee 1992). A guide for contributors of taxonomic treatments to the Flora is nearing completion.

The goal is to coordinate the publication of the Flora of the Rocky Mountains with that of Flora of North America, although the plant families occurring in two volumes of FNA will be covered in one volume of the Flora. The Flora volume will be published approximately two years after the corresponding ones for North America. Consequently, the Flora will be written along the lines of FNA. That is, in the pejorative, it will be a "flora by committee." More correctly, it will be a flora by experts, at least where ever possible. Although this method can lead to considerable hardship for the editor, more often than not, it leads to a greater approximation of reality with regard to the taxa recognized and thus a more enduring work. As a member of the Editorial Committee of the Flora of North America project, I am in a good position to evaluate the work of a specialist prior to inviting the individual to participate in the Flora. Unfortunately, for many authors, the Flora is queued behind the Vascular Plants of Arizona project and likely other floras.

Volume one, like the floras of North America and Intermountain Region, will consist of the introductory chapters (mentioned above) and taxonomic treatments of the ferns, fern allies, and gymnosperms. Illustrations from the ***Vascular Plants of the Pacific Northwest*** (Hitchcock et al. 1955, 1959, 1961, 1964, and 1969) and the ***Intermountain Flora*** will be used, with permission, where appropriate. For the first volume, about 25% of the taxa will need illustrations.

The area covered by the Flora (Fig. 4) includes the Canadian Rockies south of Pine Pass (Hart and Continental ranges and the Purcell and Selkirk mountains; Alberta and British Columbia), all of Montana, Wyoming, and Colorado, and portions of Washington (Stevens and Pend Oreille counties), Idaho (Bannock, Portneuf, Chesterfield, Bear River, Aspen, Caribou, and Snake River ranges and intervening areas of the southeast portion and that north of the Snake River Plains, excluding the Snake River Canyon and adjacent land below ca. 4,000 ft), Utah (La Sal, Uinta, Wasatch, and Wellsville mountains), South Dakota (Black Hills) and New Mexico (an inverted, roughly triangular area covering the north-central 20% of the state, south to the break in the mountains between Santa Fe and Albuquerque).

Justification for covering all of Montana, Wyoming, and Colorado in the Flora includes: 1) it will be useful to many more people, 2) many of the species in the plains to the east also occur in foothills adjacent to the Rockies and in intervening basins, 3) the western plains were not covered well in the ***Flora of the Great Plains*** (Great Plains Flora Association 1986) as most of the specimens studied were from herbaria in the central tier of states in that region, 4) and finally, there are several examples of major floras which overlap in coverage such as the ***Manual of Vascular Plants of Northeastern United States and Adjacent Canada*** (Gleason and Cronquist 1991) with the ***Flora of the Great Plains*** (Great Plains Flora Association 1986) and the ***Vascular Flora of the Southeastern United States*** (Cronquist 1980). Such overlaps in coverage are valuable in providing different taxonomic and regional perspectives on a flora.

Following the publication of the Flora, an atlas of the region is planned using specimen databases established at herbaria throughout the region and the latest technologies in GIS and computer cartography. This will be of tremendous use in phytogeographic, ecological, and systematic studies.

The Flora of the Rocky Mountains project represents a collective effort by the systematics community in the region and throughout North America. If the proposed Flora is to repre-

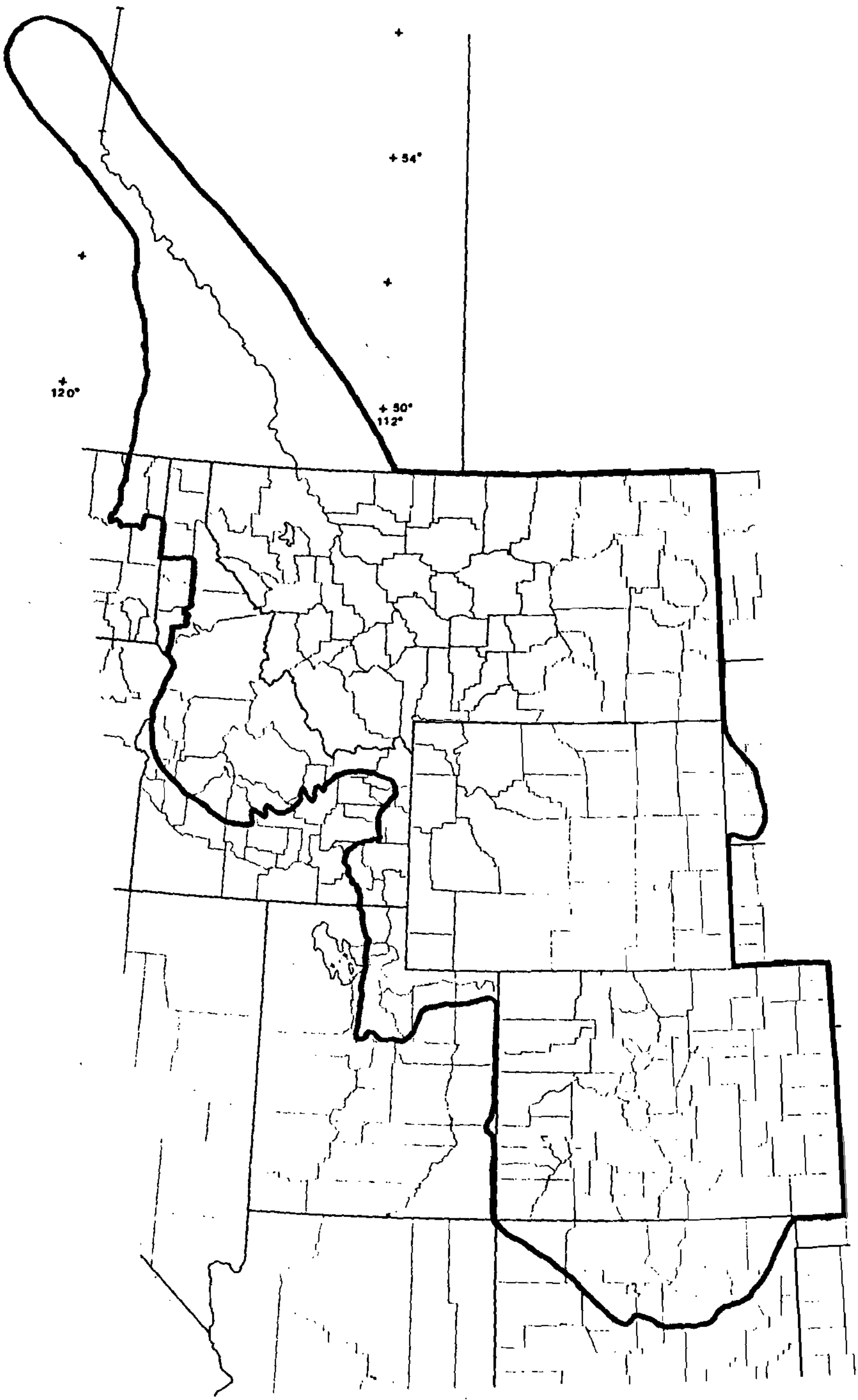

Figure 4. Proposed boundaries for the Flora of the Rocky Mountains.

sent accurately the geographical range, ecological amplitude, morphological variability, and other aspects of the vascular plants of the region, additional floristic projects will be necessary. A coordinated effort by a number of herbaria and museums is needed. Although much of the fieldwork may not be completed in time to be reflected in all of the volumes, it is hoped that the knowledge gained from these efforts will be included in a supplement to or a revision of the Flora. Such information certainly can be incorporated into specimen and taxon databases.

In conclusion, the goal is to have the Flora published within the next 12 to 15 years with help from systematists throughout North America. To this end, a Rocky Mountain Flora Association is being formed to coordinate efforts for completing of fieldwork, for the databasing of specimens, and for the preparation of the Flora.

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FLORAS OF IDAHO'S PAST: GEOGRAPHIC AND PALEOBOTANIC OVERVIEW OF THE MIDDLE MIOCENE SUCCOR CREEK FLORA AS AN EXAMPLE

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ABSTRACT—In conjunction with a tour out to the Succor Creek area (Mar. 26, 1992), the following overview of the geologic/geographic and paleobotanic setting is presented. Outcrops of the Sucker Creek Formation sediments are exposed along both sides of the Idaho-Oregon border (northwestern Owyhee and eastern Malheur counties respectively). Structurally, they consist of intra- and inter-caldera, fluvial and lacustrine (or locally air fall), tuffs, tuffaceous and/or carbonaceous sandstones, siltstones, mudstones, and locally, lignites and diatomites. Tuffs are often reworked and locally altered to clinoptilolite. In some areas the sediments are moderately to highly indurated by silica cementation or thermal metamorphosis. An age of 15 ± Ma represents the generally accepted value. In addition to diatoms, the flora consists of leaves, pollen, seeds, spores, roots, twigs, and wood. To date, at least 125 megafossil taxa and 110 palynologic taxa have been recognized in the flora. Collectively, these suggest a minimum of 200 fossil plant taxa, but include the traditional practice of counting isolated organs of taxa separately, so the actual number of biologic taxa may be somewhat less.

Key words: Paleobotany, Idaho Fossil Record, Cenozoic, Miocene, Succor Creek Flora, Sucker Creek Formation.

DEDICATION

I knew Arthur Cronquist personally for just a few short years, but by reputation for many. His passing is a loss to us all, and it is to his memory and to his love of botanical knowledge, both past and present, that I dedicate this paper. I will miss most what had become our "annual ritual" at the yearly meetings of the Botanical Society of America. I would inquire as to the current status or progress of the Intermountain Flora, and he would dutifully report how far along volume five was, or what "the hold up" was on volume three (or later on volume three part a)... We have truly lost a great man. And of this native Californian I can sincerely say, the botanical world now has another empty space where once a giant redwood stood.

INTRODUCTION

A review of Idaho's known paleobotanical record (including plants and plant-like organisms) can be summed up in a few paragraphs. Discussion of the older material (Proterozoic-Mesozoic) in the following overview largely represents a distillation of that presented by Weasma (1987), while review of the younger (Cenozoic) material was compiled by this author.

Our knowledge of Idaho's plant record starts with late Proterozoic (900-750 Ma, =million years ago) stromatolites. These consist of layers of calcareous sediments alternating with mat-like communities of cyanobacteria (blue-green algae). Northern Idaho's Gospel Peak region contains both flat-lying and conical stromatolites in rocks of the Belt Super Group.

The region now called Idaho must have spent nearly all of the time until about 350 Ma under water, for although we see many earlier marine fossils, it is not until the Mississippian Milligen Formation (ca. 340 Ma) that we find terrestrial plant fossils. These consist of rare specimens of ferns, arborescent lycopods (*Lepidodendron*), and Horsetail relatives (*Sphenophyllum*).

Other than occasional algae and stromatolites of Pennsylvanian and Permian age (i.e. 300-250 Ma), fossil plants (and plant-like organisms) are not known again from Idaho until the Cretaceous (130-65 Ma). Fresh water algae (charophytes), pollen (*Taurocusporites* and *Verricosisporites*), coal, leaves (pteridophytes and *Sapindopsis*), and wood (*Tempskya*) are known from various formations generally in the southeastern part of the state. These last three groups of plants are primarily from the Wayan Formation (100-95 Ma), of Caribou County (Crabtree 1983, 1988).

The Tertiary (65-2 Ma) record for Idaho paleobotany is more widespread, abundant, and taxonomically diverse than all earlier reports added together. It starts with middle Eocene (48-41 Ma) floras, primarily in Challis Volcanics, from Bullion Gulch, Coal Creek, Democrat Creek, Germer Basin, Hailey, Salmon, and Thunder Mountain (Brown 1937, Axelrod 1968, 1990, Edelman 1975, Wing 1988). In addition, several unpublished floras were previously interpreted as Oligocene, but are now referred to as latest Eocene (37-33 Ma) by Wolfe (1988), such as the Cow Creek flora of Lemhi County. Collectively, these floral assemblages represent mixed montane conifer-deciduous hardwood forests, such as those that are typically higher in elevation (upland) in occurrence today. These upland floras are usually dominated by fossil taxa such as: *Metasequoia, Sequoia,* numerous genera in the Pinaceae and Cupressaceae, *Alnus, Betula,* and lesser abundances of *Acer* and members of the Salicaceae, Fagaceae, and Rosaceae.

Miocene (23-5 Ma) floras abound throughout the western half of Idaho. They include: the well preserved Clarkia flora from northern Idaho (Smiley, et al. 1985) and other so-called "Latah" florules (extending from Coeur d'Alene to Whitebird, i.e., Knowlton 1926); those in the greater Weiser area (Shah 1968); those from Horseshoe Bend to Idaho City (i.e., Payette and Thorn Creek floras, Fields 1983 and Smith 1939b); the Succor Creek region (see numerous references cited below); and from the Trapper Creek (south of Burley) area (Axelrod 1964). These assemblages appear quite modern in aspect, but vary in age from about 16-12 Ma. Further, they represent a spectrum from warm temperate mixed coniferous, broadleaved deciduous, and broadleaved evergreen forests through riparian and lacustrine communities (for example see: Chaney and Axelrod 1959, Axelrod 1964, Smiley, et al. 1975, Cross and Taggart 1983, Fields 1990). Common taxonomic components are varied, but can be typified by those of the Succor Creek flora (listed and discussed below).

The later Miocene and Pliocene paleobotanical record in Idaho is known only from isolated megafossil occurrences, but rather good pollen and spore evidence. Leopold and Denton (1988) report that the mixed deciduous and conifer forests of the middle Miocene (i.e., 15-10 Ma) declined to "impoverished" levels by the late Miocene to Pliocene (5-2 Ma) in the Snake River Plain of southern Idaho, but that "Steppe elements are consistently present and increase sporadically upward in the section" from the Glenns Ferry Formation (Pliocene). By late in the section through the Hagerman lake beds, grass pollen reached peaks of up to 60% and taxa of terrestrial herbs, Asteraceae, and *Artemesia* all increased at the expense of tree pollen types (ibid.).

By mid-Pleistocene, pollen from the Bruneau Formation shows that *Artemesia* reached peaks of 50% suggesting that a true sage steppe had begun to develop (Leopold and Wright 1985), but a deciduous woody flora was still locally present (perhaps all riparian) as indicated by the ample fossil woods known from the "Bruneau Woodpile" area and by the presence of hackberry seeds. By the late Pleistocene (Yahoo Clay), sage and other Asteraceae had reached pollen peaks of up to 80% of the taxa present (Leopold and Denton 1988). For the Holocane, Davis (1984, Davis, et al. 1986) used inferred paleoelevation of the ecotone between the shadscale and sagebrush steppe vegetation from various study sites in the Snake River Plain to infer a July maximum insolation (and thermal maximum) at around 10,000-8,000 years ago. Chenopodiaceae and *Amaranthus* pollen (types indicative of shadscale vegatation) apparently reached their highest peaks about 7,400 years ago in those central-southern Idaho sites (Davis, et al. 1986).

Modern pollen rain from transects across the center of the Snake River Plain suggests an abundance of sage, grasses, and saltbush (Chenopodiaceae and *Amaranthus*), with elevated conifer levels only near the mountains (Leopold and Wright 1985).

In summary, these Cenozoic data suggest that the diverse deciduous and conifer rich forests of the early and middle Miocene began to decline perhaps 10 Ma, giving way to open grassland steppe by about 2 Ma. This in turn gave way to sagebrush steppe and ultimately to shadscale/saltbush dominated vegetation (in the lowlands) by the early Pleistocene.

THE SUCKER CREEK FORMATION

The Succor Creek[1] region is located along the Owyhee County, Idaho and Malheur County, Oregon state line (Fig. 1). The fossil-bearing outcrops consist of volcanic rocks referred to as the Sucker Creek Formation (Corcoran, et al. 1962, Corcoran 1965, Kittleman, et al. 1965, 1967, Kittleman 1973). The total possible age range for the Formation is about 16-11 Ma (Ekren, et al. 1981, 1984), with a generally accepted range of about 16-14 Ma (Cross and Taggart 1983). However, recent reports suggest a younger age of about 14.5-11.5 (Ferns 1989, MacLeod 1990). The region is interpreted structurally as a series of fluvial and lacustrine (or locally air fall), intra- and inter-cladera deposits; consisting of tuffs, tuffaceous and/or carbonaceous sandstones, siltstones, mudstones, and locally, lignites and diatomites. The tuffs are often reworked and locally altered to clinoptilolite (a type of zeolite). In some areas the sediments are moderately to highly indurated by silica cementation or thermal metamorphosis, leaving "porcellanite", "cherts", and/or cobble-conglomerate deposits containing large petrified tree trunks (Rytuba, et al. 1985, Walden 1986, Vander Meulen, et al. 1987a. b. c. Vercoutere, et al. 1987, Ferns 1988, 1989, MacLeod 1990).

THE SUCCOR CREEK FLORA

To date, there are over 100 megafossil-bearing sites known from throughout the greater Succor Creek region (Figure 1). The vast majority of these sites contain relatively small numbers of fossil remains of poor quality, but each site, when properly sampled (Fields 1988), adds valuable information to our understanding of the region during the middle Miocene. Additionally, throughout most sites tested to date, there is a useful palynologic sequence that further adds to our knowledge of the area (i.e., Taggart 1971, Cross and Taggart 1983, Satchell 1983).

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[1] Distinction between the two spellings for "Succor" Creek (vs. "Sucker" Creek) have been discussed in detail elsewhere, for example see: Graham 1965, Eubanks 1966, and Fields 1983 appendix III. The presently accepted usage is to identify the geologic formation as "Sucker Creek" and to use "Succor Creek" for all other purposes, except when quoting past usage.

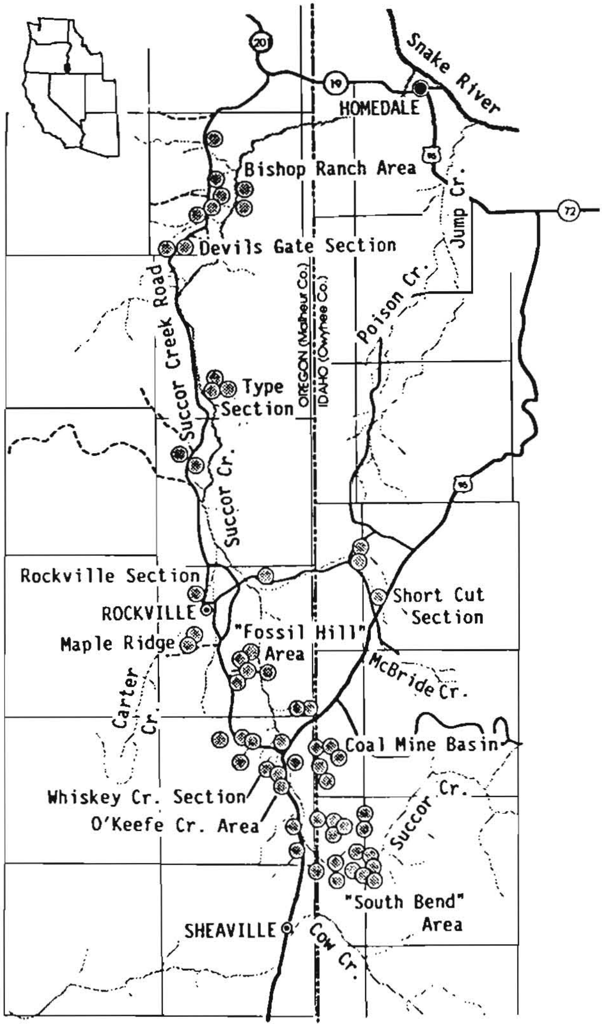

Figure 1. Overview of the major areas from which Succor Creek floral assemblages have been collected throughout the greater southwestern Idaho/ eastern Oregon region. Each stippled circle represents one to many fossil bearing sites. Each solid circle represents a town/city site (labeled in capital letters). Each square represents a township (ca. 10 km by 10 km). Figure redrawn and modified by Patrick F. Fields and Peter Carrington from Taggart and Cross (1980).

Table 1. RECOGNIZED TAXONOMIC DIVERSITY OF THE SUCCOR CREEK FLORA OVER TIME (Updated and modified from Fields 1990)

	# Fossil Taxa			# Figured Specimens	
Citation	**Meg-**	**Palyn**	**LNTC**	**Meg-**	**Palyn**
Knowlton in Lindgren 1900	20	/	20	0	/
Knowlton in Russell 1903	9+	/	9+	0	/
Knowlton in Lindgren & Drake 1904	18	/	18	0	/
Berry 1932	11	/	11	1	/
Brooks 1935	28	/	28	22	/
Arnold 1936a (*Mahonia* only)	4+	/	4+	4	/
Arnold 1936b (*Cedrela* only)	2+	/	2+	2	/
Arnold 1937	23+	/	23	19	/
Smith 1938	12	/	12	12	/
Smith 1939a	30	/	30	19	/
Smith 1940	60	/	60	0	/
Chaney and Axelrod 1959	55	/	55	4	/
Graham 1963	70	46			
Axelrod 1964	52	/	52	0	/
Graham 1965	71	ca. 50	70	42	43
Eubanks 1966 (Wood only)	15+	/	67	1	/
Taggart 1971 (PhD)	41	90-91	124	0	89+ 17unk
Cross, Taggart, and Parker 1971	6+	22-23	27+	0	0
Taggart 1973	5	9	15+	2	8
Tanai and Wolfe 1977 (Ulmaceae only)	4	/	4+	0	/
Taggart and Cross 1980	60	80	100+	0	0
Cross & Taggart 1983	69	75+	75+	0	0
Satchell 1983 (PhD)	38+	47	72+	0	10
Wolfe and Tanai 1987 (*Acer* only)	10	/	10+	5	/
Fields 1990	120-27	122-39	200-11	0	0
Minimum number of taxa*	125-35	122-39	200-11		
# taxa unique to each group	66	76			

("Meg-" = megafossils, "Palyn-" = Palynmorphs, "LNTC" = lowest number of taxa in common, "/" = Palynmorphs not addressed in this paper. * -based upon summary of above and new discoveries either collected by this author or observed by this author in museum, university, or private collections).

In addition to the diatoms and other algae, pollen, and spores (referred to above), the flora consists of cones, fruits, leaves, seeds, shoots, and wood (roots, stems, and twigs).

Our concept of the fossil floral diversity in the Succor Creek flora has changed steadily over time from the initial report of leaves at the turn of the century (Knowlton in Lindgren 1900); through monographs by Brooks (1935), Smith (1938, 1939a, 1940), and Graham (1965); to the most recent publications by workers from Michigan State University (Taggart 1971, 1973, Taggart and Cross 1980, 1990, Taggart, et al. 1982, Cross and Taggart 1983, Satchell 1983, and Fields (1989, 1990, 1991). Table 1 lists 25 papers that cite and/or illustrate Succor Creek floral material, and discusses the number of recognized megafossils and palynomorphs in each paper.

A list (Table 2) was compiled, summarizing the known Succor Creek lower- and nonvascular taxa and showing all the gymnosperm and angiosperm taxa by family and genus. Table 3 summarizes the taxa totals by major plant group. Sources of new names recognized in the flora are primarily from two areas: the literature and from collections (both existing and newly made).

In the course of a thorough literature review of all known scientific papers relating to the Succor Creek flora of the Oregon/Idaho border area, references were found to many fossil plant taxa that were apparently not summarized in any single place. Some of the reasons for these omissions appear to be: 1) old names that had been synonymized to other taxa (when an older validly published name was discovered), 2) misidentifications that some later worker had corrected, 3) new discoveries that were apparently found after the most recent comprehensive overview article (that is, since Graham 1965), and 4) some appear to be validly identified taxa that, for some reason, had not been recognized by subsequent workers. The first two categories above were correctly omitted from summary lists, but the latter two needed to be incorporated.

An additional, much smaller, source of names new to the flora is from new discoveries (both to science and previously known, but new to the flora). Examination of extant and newly made museum, university, and private collections has yielded a number of taxa new to the flora. Many of those that are new to the flora are listed here, but those as yet undescribed (i.e. new to science) are omitted.

The major holdings of Succor Creek floral material (ranked approximately by size) are located at: Michigan State University (East Lansing); the O.J. Smith Museum of Natural History at the Albertson College of Idaho (Caldwell); a Private Collection (Aurora, Colorado); the University of Michigan (Ann Arbor); the U.S. National Museum (Washington, D.C.); and the Carnegie Museum of Natural History (Pittsburgh, Pennsylvania).

NUMERICAL SUMMARY OF THE FLORA

As suggested in Table 1, the recognized floral diversity in the middle Miocene of the Succor Creek area has increased dramatically over the last century, but it wasn't until a recent summary of all past studies, combined with new intensive field work (Fields 1990), that the reported totals dramatically increased.

To date, at least 125 megafossil taxa and 122 palynologic taxa have been recognized in the Succor Creek flora (summarized in Table 3). The taxa are distributed throughout at least 55 plant families and 94 genera. In addition to the nonvascular and lower vascular groups, the gymnosperms are represented by members of 7 families, 18 genera, and 24 species, whereas the angiosperms are represented by a minimum of 43 families, 70 genera, and 123 species. All taxa taken collectively suggest a minimum of 200 fossil plant taxa plus numerous unknowns, including the traditional practice of counting isolated organs of taxa as separate morphospecies and including at least 41 palynomorphs of fungi and/or nonvascular plants. Thus, the number of fossil names assigned to the flora is artificially high, the true number of fossil biologic taxa may be somewhat less, and the actual number of fossil vascu-

Table 2. TENTATIVE LIST OF THE GREATER SUCCOR CREEK FLORAL DIVERSITY (Compiled by Patrick F. Fields)

Major Plant Group	Taxon	Organ (# of Taxa)
LOWER VASCULAR & NON-VASCULAR PLANTS		
Acritarchs	Three or more groups	P (4)
Algae	At least four groups	P (9+)
Fungi	Many groups	P(24)
Lycopsida	*Lycopodium*	P(2)
Pteridopsida	*Davallia, Osmunda, Polypodium, Woodwardia*	P,F (8)
Sphenopsida	*Equisetum*	P,R,Sh (2-3)
VASCULAR PLANTS OF UNCERTAIN AFFINITY: At least four groups		P (4)
GYMNOSPERMS		
Cupressaceae	*Calocedrus, Cupressus, Thuja*	P,Sh (3)
Ephedraceae	*Ephedra*	P
Ginkgoaceae	*Ginkgo*	L
Pinaceae	*Abies, Cedrus, Keteleeria, Picea Pinus, Pseudotsuga, Tsuga*	L,P,S,Sh,C,W (13+)
Podocarpaceae	*Podocarpus*	P
Taxaceae	*Cephalotaxus (or Amentotaxus)*	PL
Taxodiaceae	*Glyptostrobus, Metasequoia, Sequoia, Taxodium*	P,C,Sh,W(4)
ANGIOSPERMS - DICOTS		
Magnoliaceae	*Magnolia*	Fr,L(?)
Lauraceae	*Persea, Sassafras, Umbellularia*	L.W (3)
Nymphaeaceae	*Nymphaea.*	L.P.Rh
Berberidaceae	*Mahonia*	L,P (6)
Platanacaeae	*Platanus*	Fr,L,P,W
Hamamelidaceae	*Liquidambar*	L.P
Ulmaceae	*Celtis, Ulmus, Zelkova*	L,P.W (7)
Juglandaceae	*Carya, Juglans, Pterocarya*	L.P (3)
Fagaceae	*Castanea, Castanopsis, Fagus, Lithocarpus, Quercus*	L.P,Fr,W(9-11)
Betulaceae	*Alnus, Betula, Carpinus. Corylus, Ostrya*	L.P.Fr,S,W (7)
Chenopodiaceae-Amaranthaceae	*Sarcobatus & 3-4 others*	P (4-5)
Tiliaceae	*Tilia*	Br.L,P
Malvaceae	*Anoda, Sphaeralcea*	L.P (3)
Salicaceae	*Populus, Salix*	L.P,Fr,W (9)
Ericaceae	*Arbutus, Vaccinium*	L,P.W (2-3)
Ebenaceae	*Diospyros*	Br,L
Hydrangeaceae	*Hydrangea*	L,Calyx
Grossulariaceae	*Ribes*	L
Rosaceae	*Amelanchier, Crataegus, Photinia, Prunus. Pyrus, Rosa*	L.P,Sh,F,W(6)
Leguminosae (Fabaceae sensu lato)		P(polyad),Sh
Caesalpiniaceae	*Gymnocladus*	L,Fr
Fabaceae (Papilionaceae)	*Cladrastus, Sophora*	L.Fr (2)
Eleagnaceae	*Shepherdia*	P
Onagraceae	*Epilobium (?)*	P (3)
Nyssaceae	*Nyssa*	L.P.Fr (1-2)

Table 2. TENTATIVE LIST OF THE GREATER SUCCOR CREEK FLORAL DIVERSITY (*continued*)

Major Plant Group	**Taxon**	**Organ (# of Taxa)**
Cornaceae	*Cornus*	L,P
Aquifoliaceae	*Ilex*	L,P (2)
Buxaceae	*Pachysandra*	P
Malpighiaceae	*Hiraea*	L,S
Aceraceae	*Acer*	L,P,S,W (10)
Anacardiaceae	*Rhus*	L
Simarubiaceae	*Ailanthus*	L,S
Meliaceae	*Cedrela*	Fr,L,S
Rutaceae	*Evodia (=Melicope + Tetradium), Ptelea*	L,S,W (2)
Araliaceae	*Oreopanax*	L
Apiaceae (Umbelliferae)		P
Oleaceae	*Fraxinus*	L(?),P,S,W (2-3)
Caprifoliaceae	*Symphoricarpos*	L,P
Asteraceae (Compositae)	*Ambrosia, Artemesia, High & Low Spine*	P (16)
ANGIOSPERMS - MONOCOTS		
Potamogetonaceae	*Potamogeton*	P
Cyperaceae	*Carex*	L
Poaceae (Gramineae)	*Cyperacites*	L,P (3)
Typhaceae	*Typha*	L,P
Smilacacea	*Smilax*	L
Total Number of Fossil Taxa Recognized		200-207+

Key to Letters and Symbols:
Br= bract, C= cone, F= fern frond, Fr= fruit, L= leaf or leaflet, P= pollen & spores, R= rhizome, S= seed, Sh= shoot, W= wood, (24)= 24 morphotypes of this taxon honored, (9+)= at least 9 taxa honored. The non-vascular and lower vascular plants are arranged alphabetically by major plant group, the gymnosperms are arranged alphabetically by family, and the angiosperms are arranged according to the Cronquist System (Cronquist 1981).

Table 3. SUCCOR CREEK FLORAL DIVERSITY SUMMARY

Major Group	**Families**	**Genera**	**Species**
Fungi, Acritarchs, Algae, Lycopsids, and unk. (all palynomorphs)	many	many	43+
Sphenopsida (horsetails)	1	1	2-3
Pteridopsida (ferns)	4	5-8	8
Gymnosperms (*Ephedra* & conifers)	7	18	24+
Angiosperms (dicots)	38-39	65+	116-122+
(monocots)	5	5	7
Total Number of Fossil Taxa Recognized	55-56+	94-97+	200-207+

lar biologic taxa is smaller still (Fields 1990). Just over 20 percent of the total recognized floral diversity (43/200 taxa) is made up of all the non-vascular and lower vascular taxa, represented only by palynomorphs (Table 3). Further, members of eight vascular plant families comprise about 40 percent of the diversity (84/200, Table 2). Thus, about 60% of the total diversity in the flora can be accounted for by these two groups. The eight most diverse vascular plant families are: Asteraceae (16 taxa, all known only from pollen), Pinaceae (13 taxa), Aceraceae and Fagaceae (about 10 taxa each), Salicaceae (9 taxa), Betulaceae and Ulmaceae (7 taxa each), and Berberidaceae and Rosaceae (6 taxa each). The remaining 40% of the total diversity is distributed through 46-47 plant families (Table 3).

WHY SUCH HIGH TAXONOMIC DIVERSITY?

Many distinct factors appear to have contributed to the high taxonomic diversity now known from the Succor Creek flora. They include: the total geographic area over which the Sucker Creek Formation outcrops and from which fossils have been collected (ca. 50 km N-S by 8-14 km E-W); the lithology is predominantly volcanic in origin, suggesting frequent volcanic disturbance by both volcanic eruption (Taggart and Cross 1980) and eruption-induced fires (Satchell 1983), resulting in an ecologically diverse landscape; the depositional setting and environment consisted of a series of intra- and inter-caldera (Rytuba, et al. 1985, Vander Muelen, et al. 1987a, b, c), more or less ephemeral lakes and ponds (Cross and Taggart 1983); the paleogeographic setting varied around and between these calderas, as well as over a southward increasing elevational gradient (Cross and Taggart 1983, Fields, et al. 1990). In addition to these factors, the interval of time may be significant.

As discussed above under the heading "Sucker Creek Formation", there could be as much as a five million year "window" (16-11 Ma) of time represented by the Sucker Creek deposits. Most workers would accept about two million years as a functional and more realistic interval over which the flora lived and was preserved in these sediments (i.e. Cross and Taggart ibid.). Estimates of the time required to deposit the observed thicknesses of rocks in the formation range from about 10,000 years per given stratigraphic section (Cross and Taggart ibid.) to perhaps double that value (based upon new unpublished data on longer sections). However, the exact stratigraphic relationships of many sections to one another are not known. Further, exactly where in the five million year "window" the two million year interval occurs is at present a matter of debate (see above), and where in the two million year smaller "window" the 10-20,000 years worth of sedimentation per section should be placed is unknown. Finally, whether these sediments are continuous or discontinuous (within and between sections), and/or evenly distributed or localized throughout the two million years is unknown. Consequently, the time involved could encompass a great deal of variation in paleoclimate, floral succession and/or evolution, disturbance frequency, and environments of deposition. Collectively, any or all of these factors could have contributed to an increase in floral diversity of the Succor Creek fossil record.

Thus, the Succor Creek flora of southwestern Idaho and eastern Oregon may now be considered one of the most well-studied floras in the United States and perhaps the world. Intensive multidisciplinary investigations (both systematic and ecologic) create a truly unique level of understanding of the flora. A greater knowledge of the high taxonomic diversity and ecologic heterogeneity in such a dynamic setting, has in turn, allowed us a whole new appreciation of the middle Miocene floral dynamics of the Pacific Northwest.

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FLORISTIC REGIONS OF IDAHO

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INTRODUCTION

At the outset, it is important to establish what this presentation is, and what it isn't. What it is, is the current stage of an attempt to synthesize available knowledge of the Idaho flora in the form of delineated floristic units, similar to (and to a large extent inspired by) Hickman's (1989) floristic subdivisions of California. What it isn't, is an exhaustively researched and experimentally tested finished product. Rather, what is presented here should be considered a starting point, a preliminary hypothesis made available for testing, refining, challenging, and generally reworking as necessary.

Another factor that must be addressed is "why". Why bother trying to recognize floristic units? Why draw lines where nature has, at best, gradual transitions? The answer is the same reason that we draw lines around other units of nature, be they species, kingdoms, mountain ranges, or vegetation types. We draw lines to create categories, which we then use for our own purposes. We see three primary uses of the floristic categories presented here.

First is **organization** of knowledge. Suggested codes are provided for use in databases, a very important means of organizing knowledge. At the most mundane level, a system now exists for filing our slides of Idaho, especially the ones used in this symposium! At a more challenging level, each floristic region is a reasonable focus for separate floras, perhaps as Master's thesis projects, which could eventually form the basis for an updated Flora of Idaho.

Second, formalized units facilitate **communication**, especially in describing the range of a species both effectively and efficiently. Saying that a certain plant occurs in "the mountains of eastern Idaho" could as readily include the Wasatch Range as the Bitterroots, while political categories such as Elmore County can include very different deserts and forests.

A third use is in **planning**, becoming ever more important as environmental issues are coming to the fore. Of course, this can be accomplished with strictly artificial lines, particularly pre-existing county lines and national forest boundaries. Such artificial categories have their own advantages and will certainly not go out of use. However, units that emphasize natural boundaries have a greater predictive value in determining how translatable expertise and effective policies are from one area to another.

METHODS

Attempts to divide Idaho into floristic subdivisions are certainly nothing new, but little has been formalized at a level comparable to those of Hickman's (1989) for California. Standard plant geography references (e.g., Takhtajan, 1986) paint too broad a picture, while Arnold's

(1975) physiographic analysis of the Idaho Batholith is too detailed. Likewise, although we had access to the U.S. Forest Service's prototype vegetation map, the details were generally finer than needed.

There was also a lack of consensus; for example, Holmgren (1972) includes the mountains of southeastern Idaho in the Intermountain Region, while other treatments (e.g., Hunt, 1974) include these with the Yellowstone Plateau in the Middle Rocky Mountains. Omernik and Gallant (1986) combine the Snake River Basin with the High Desert as a single unit extending all the way to the Cascade Mountains, and McLaughlin (1989) further lumps this unit with the Columbia Plateau (based, however, upon a sample of only four included local floras).

As a result, although information in published sources has been incorporated whenever relevant, the floristic units presented here represent much more a synthesis of unpublished personal knowledge, the realization that field botanists develop that they're "someplace different". This includes not only the first-hand field experience of the authors, but perhaps more importantly the floristic knowledge and traditions accumulated in southern and northern Idaho at Albertson's College of Idaho and the University of Idaho, respectively. In particular, we acknowledge the contribution of our mentors at these institutions, Patricia L. Packard and Douglass Henderson. We are also indebted to Frederic Johnson, also of University of Idaho, for sharing some of his insights on a similar project done in conjunction with Bob Steele (U.S. Forest Service) but never published.

The most important supplementary information used in analysis and delineation of floristic regions was geology, the primary determinant of plant distribution. Substrate, physiography, and geological history all have direct effects on vegetation and are major determiners of soil type and climate. Because of the comprehensive nature of this floristic synthesis, the most useful and accessible sources of relevant geological information were similarly broad scale. In addition to the 1:500,000 scale Geologic Map of Idaho (Idaho Department of Lands, Bureau of Mines and Geology, 1978), these sources included the popularized summaries of Idaho geology by Maley (1987) and, to a lesser extent, Alt and Hyndman (1989). Pre-Pleistocene events are incorporated into the discussions of each floristic subdivision, not because of their direct effect on current plant distribution but because they explain the geology that does effect the plants (as well as being fascinating in their own right!)

In addition to the Geological Map of Idaho, other maps were used as available. The 1:500,000 scale Idaho map by Raven Maps and Images (1988) was particularly useful for incorporating physiography/elevation. Some useful soil information was obtained from the Soil Conservation Service's (1973) General Soil Map of Idaho.

RESULTS AND DISCUSSION

The currently proposed floristic subdivisions are shown in Figure 1. There are a total of 34 minor subdivisions grouped into 11 major subdivisions, as summarized in Table 1. Plastic sheet overlays, suitable for 1:500,000 scale maps, are being deposited at the herbaria of the University of California, University of Idaho, Albertson College of Idaho, Idaho State University, Brigham Young University, University of Wyoming, and New York Botanical Garden.

1. Panhandle Division (PH)

The northernmost major subdivision coincides with the maximum extent of the Purcell lobe of the continental ice sheet during the Pleistocene. As a result, not only were the mountains heavily glaciated, but the valleys were as well. On the southern border, ice periodically dammed the Clark Fork to form Lake Missoula in the valleys of Montana. The massive floods resulting whenever the ice dam was breached scoured the scablands of eastern Washington, carving out Grand Coulee.

The impact of Pleistocene ice is responsible for many of the dominant landscape features of this division. Continental ice extending south from Canada scoured three large val-

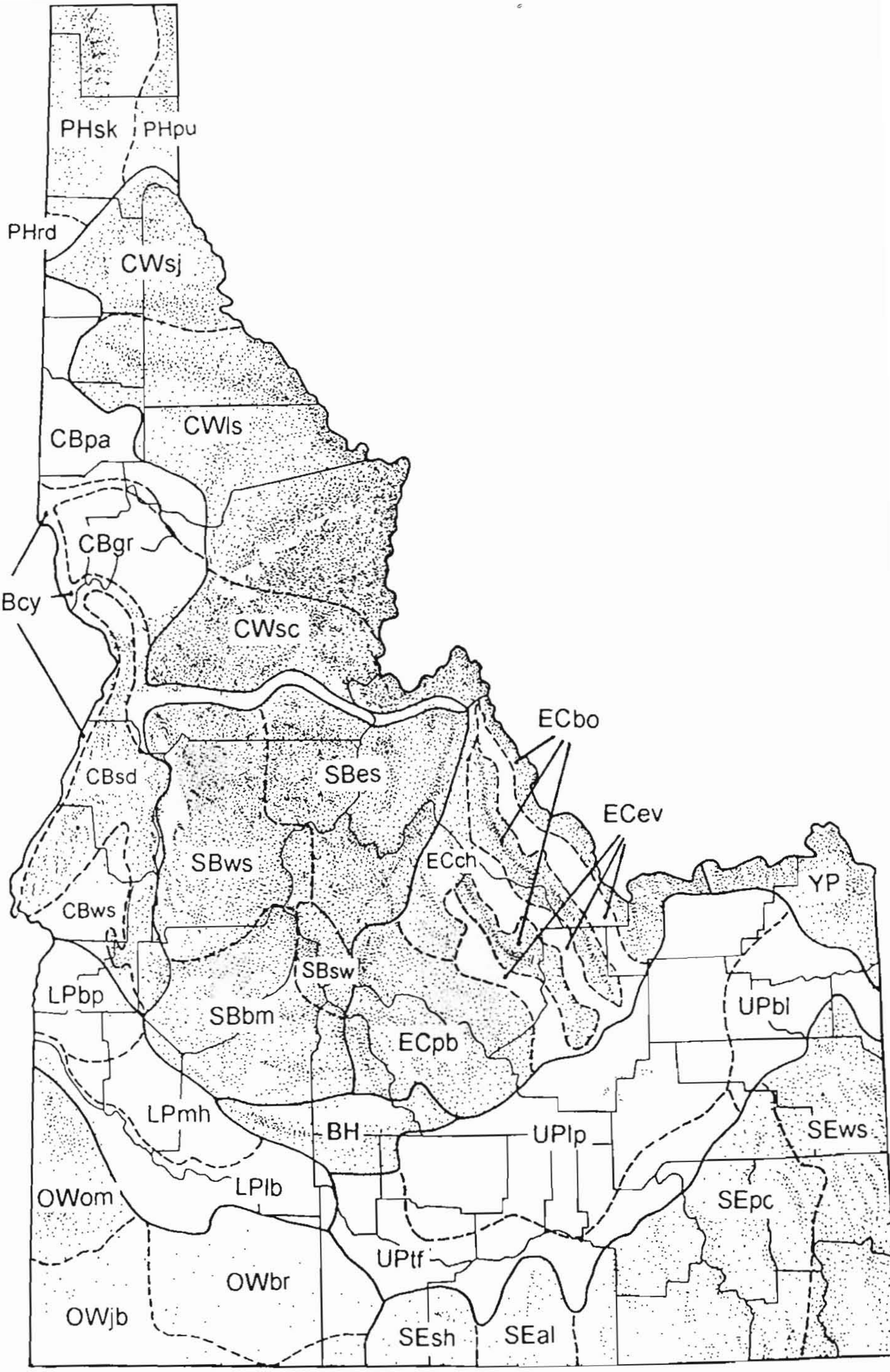

Figure 1. Map of Idaho Outlining the State's Proposed Floristic Regions.

Table 1. Summary of Idaho Floristic Regions.

1. Panhandle Division	PH
1a. Selkirk Unit	PHsk
1b. Purcell Unit	PHpu
1c. Rathdrum Unit	PHrd
2. Columbia Division	CB
2a. Palouse Unit	CBpa
2b. Grangeville Unit	CBgr
2c. Canyons Unit	CBcy
2d. Seven Devils Unit	CBsd
2e. Weiser Unit	CBws
3. Clearwater Division	CW
3a. St. Joe Unit	CWsj
3b. Lochsa/Selway Unit	CWls
3c. South Clearwater Unit	CWsc
4. South Batholith Division	SB
4a. Western Salmon River Mountains Unit	SBws
4b. Eastern Salmon River Mountains Unit	SBes
4c. Boise Mountains Unit	SBbm
4d. Sawtooth Unit	SBsw
5. East-Central Mountains Division	EC
5a. Pioneer/Boulder Unit	ECpb
5b. Borah Unit	ECbo
5c. East-Cental Valleys Unit	ECev
5d.. Challis Unit	ECch
6. Yellowstone Plateau Division	YP
7. Upper Snake River Plain Division	UP
7a. Lava Plains Unit	UPlp
7b. Bottomlands Unit	UPbl
7c. Twin Falls Unit	UPtf
8. Lower Snake River Plain Division	LP
8a. Boise/Payette Valleys Unit	LPbp
8b. Mountain Home Unit	LPmh
8c. Lakebed Unit	LPlb
9. Bennett Hills Division	BH
10. Owyhee Division	OW
10a. Owyhee Mountains Unit	OWom
10b. Bruneau Plateau Unit	OWbr
10c. Jarbidge Uplands Unit	OWjb
11. Southeastern Mountains Division	SE
11a. South Hills Unit	SEsh
11b. Albion Unit	SEal
11c. Pocatello Unit	SEpc
11d. Wasatch Unit	SEws

leys. The Purcell Trench is the largest, bisecting the division, with the Priest River Valley to the west and the Moyie River valley on the east. Possibly due to its proximity to a continental ice sheet, alpine glaciation in this division was particularly intense for Idaho. Although the mountain ranges here are not high, with maximum elevation of approximately 2380 m, mountain glaciation created rugged terrain with relatively high relief.

Precipitation and humidity are relatively high in this division, fostering numerous species characteristic of the Pacific Northwest, many of them disjunct. *Tsuga mertensiana* (Bong.) Carr, however, is conspicuously absent.

1a. **Selkirk Unit** (PHsk): the Selkirk Mountains, as well as the Priest River Valley and, tentatively, the Purcell Trench. This unit is underlain largely by granite in the mountains, formed from the Cretaceous Kaniksu Batholith, and alluvial deposits in the valleys. Unifying floristic characteristics include the dominance of *Rhododendron albiflorum* Hook. in the understory of subalpine forests and the presence of *Leptarrhena pyrolifolia* (D. Don) R. Br., *Romanzoffia sitchensis* Bong., and *Ribes howellii* Greene in these same forests. Sphagnum substrates occurring in glacial kettles in the valleys contain several boreal species, such as *Carex chordorrhiza* Ehrh. ex L. f. and *Gaultheria hispidula* (L.) Muhl., that do not occur in similar habitats elsewhere in the state.

1b. **Purcell Unit** (PHpu): Purcell and Cabinet mountains. This unit is underlain almost entirely by metamorphosed sediments of the Precambrian Belt Series. Two deep valleys traverse the unit: the Moyie River Valley bisects the Purcell Mountains and the Kootenai River Valley separates the Purcell Mountains on the north from the Cabinet Mountains on the south. The rugged mountains of this unit are covered by relatively rich coniferous forests. *Betula pumila* L., a boreal tree, occurs in bog and fen habitats exclusively in this unit in Idaho.

1c. **Rathdrum Unit** (PHrd): Rathdrum Prairie, through which the floodwaters from Lake Missoula poured. Because the Rathdrum Prairie was the Pleistocene drainage for outwash from the continental icesheets to the north, well-drained sandy substrates underlie much of the area. Virtually no free water occurs on the prairie surface, although a large aquifer flows beneath it.

Nearly all of the Rathdrum Prairie is presently under cultivation, but the one small prairie remnant known has *Festuca scabrella* Torr. and *F. idahoensis* Elmer codominating a community that is rich in forbs. The prominence of *F. scabrella* is one of the main differences between this unit and the Palouse Prairie, where it occurs only at the northern edge.

2. Columbia Division (CB)

This division is a heterogeneous grouping of intertwined geology and physiographic features, loosely connected by the Columbia River Basalt flows, which define most of the boundaries. The geologic history is both complicated and fascinating. This was the western continental margin during the Mesozoic, with an active subduction zone. As a result, oceanic terranes were accreted, notably the Seven Devils and Cuddy mountains in Idaho and the Wallowa Mountains opposite Hells Canyon in Oregon. All lower elevations were then covered by massive outpourings of Columbia River Basalt in the Miocene, through which the Snake, Salmon, and Clearwater rivers cut deep, steeply walled canyons.

Prior to cultivation and grazing, the prairies, hills, and canyons were dominated by perennial bunchgrasses, especially *Agropyron spicatum* (Pursh), Scribn. & Smith, *Festuca idahoensis*, and *Poa secunda* Presl. This vegetation type is still relatively intact in the canyons but has been largely converted to agriculture on the prairies.

2a. **Palouse Unit** (CBpa): the eastern portion of the Palouse Prairie that extends into Idaho, partly coinciding with the St. Maries Embayment of the Columbia Plateau. It formerly consisted of rolling grasslands and forested hills, interfingering with the Clearwater Mountains to the east. Because of the exceptionally rich soil, a deep layer of loess, most of the grasslands have been converted to agriculture. Most of the Palouse Prairie vegetation has therefore disappeared, and endemic species such as *Aster jessicae* Piper and *Haplopappus liatriformis* (Greene) St. John are threatened with extinction.

2b. **Grangeville Unit** (CBgr): Camas Prairie south of the Clearwater River and Joseph Plains south of the Salmon River, partly coinciding with the Clearwater Embayment of the Columbia Plateau. These prairies average 300 m higher elevation than the Palouse Prairie, and are correspondingly moister and cooler. Like the Palouse Prairie, however, they are underlain by deep loess and are therefore likewise largely converted to agriculture.

2c. **Canyons Unit** (CBcy): the steep-sided canyons of the Snake, Salmon, and Clearwater rivers, often several thousand feet deep. The lowest elevation in Idaho, ca 312 m, is where the Clearwater and Snake rivers meet and exit the state near Lewiston. The Salmon River Canyon extends far eastward, bisecting the Idaho Batholith and creating a low elevation corridor for the canyon flora into the mountainous regions of central Idaho.

The flora at the bottom and sides of the canyons differs dramatically from that of the adjacent forests and prairies, and the diverse layers of exposed geology have further encouraged the development of endemic taxa. In Hells Canyon these include *Ribes cereum* Dougl. var. *colubrinum* Hitchc., *Lomatium rollinsii* Math. & Const., *L. serpentinum* (M. E. Jones) Math., *Penstemon elegantulus* Pennell, and *Mirabilis macfarlanei* Constance & Rollins, Idaho's only Federally listed species.

2d. **Seven Devils Unit** (CBsd): the forested mountains between Hells Canyon and the Idaho Batholith, including the Seven Devils, Cuddy, Council, and West mountains. Basalt is the dominant substrate, but the Seven Devils Mountains, in particular, are geologically complex. As former oceanic islands comprised largely of metamorphosed volcanics, they include about the only serpentine in Idaho, though not in sufficient quantities to develop a distinct serpentine flora. Many of the species found in the Pacific maritime influenced forests of northern Idaho reach their southern limits here: for example, *Larix occidentalis* Nutt. and *Abies grandis* (Dougl.) Forbes.

2e. **Weiser Unit** (CBws): the unforested valleys and mountains at the south end of the Columbia River Basalts, largely coinciding with the Weiser Embayment. This includes not only the Weiser River valley but also, tentatively, Squaw Butte and Horseshoe Bend Hill. Indian Valley, where the presumed extinct *Carex aboriginum* M. E. Jones was once found, is part of this unit.

Floristically this unit is transitional to the Lower Snake River Plain Division, but the heavy clay soils and scablands support certain plants more characteristic of the Columbia Plateau. This includes thick-rooted *Lomatium* species, falcate-leaved *Allium* species, and subshrubby *Eriogonum*, such as *E. thymoides* Benth. and *E. sphaerocephalum* Dougl. Unlike the other non-forested units in this division, shrubby *Artemisia* species such as *A. tridentata* Nutt. and *A. rigida* (Nutt.) Gray are dominant.

3. Clearwater Division (CW)

The mountains of northern Idaho between the Panhandle and the Salmon River are relatively uniform compared to some other floristic divisions. The Clearwater Mountains on the west gradually rise to join with the Bitterroot Mountains on the Montana border. The geology consists primarily of Precambrian Belt metamorphics and Cretaceous batholith granites. This division contain much of Idaho's best forest lands, with a good diversity of conifers, and as a result is being extensively clearcut.

Of particular floristic interest is the number of taxa disjunct from west of the Cascade-Sierran axis, such as *Cornus nuttallii* Aud., *Dodecatheon dentatum* Hook., *Carex hendersonii* Bailey, *Mertensia bella* Piper, and *Polypodium glycyrrhiza* D. C. Eat. This disjunction was the subject of a master's thesis by Christine Lorain (1988, University of Idaho, College of

Forestry, Wildlife, and Range Sciences), who concluded that the various river drainages where they occur constitute Pleistocene refugia.

3a. **St. Joe Unit** (CWsj): the St. Joe and Coeur d'Alene mountains, north of the St. Joe River. The geology is almost exclusively Belt Series metasediments, not as heavily glaciated as units to the north, that were covered by continental ice, or the units to the south that contain high elevation massifs.

The relatively low, rounded mountains are dominated by a mesic coniferous forest of *Thuja plicata* Donn., *Tsuga heterophylla* (Raf.) Sarg., *T. mertensiana*, *Pinus monticola* Dougl., and *Abies grandis*, among others. The northern limit of the unit coincides with the northern limit of *Tsuga mertensiana* in Idaho (which coincides with the southern extent of continental ice), while the southern boundary coincides with the southern limit of *Tsuga heterophylla*. The low elevation canyons of the Coeur d'Alene and St. Joe rivers harbor some coastal disjunct taxa, but not as many as the Lochsa/Selway Unit to the south.

3b. **Lochsa/Selway Unit** (CWls): between the St. Joe River and the Selway River/South Fork Clearwater River divide. *Thuja plicata*, *Pinus monticola*, and *Tsuga mertensiana* generally do not occur south of this hydrologic boundary. The moist, low-elevation canyons of the North Fork Clearwater, Lochsa, and Selway rivers create an environment similar to that west of the Cascades and, as a result, harbor many taxa disjunct from that region. Notable endemics include *Dasynotus daubenmirei* Johnst., *Corydalis caseana* Gray var. *hastata* (Rydb.) Hitchc., and *Synthyris platycarpa* Gail & Pennell.

3c. **South Clearwater Unit** (CWsc): between the Selway-South Fork Clearwater River divide and the Salmon River canyon. This unit is floristically transitional to the units south of the Salmon River and could as justifiably be associated with them as with the other Clearwater units.

An interesting floristic feature is the abundance of *Taxus brevifolia* Nutt., which, near the southern limit of its distribution in this unit, occurs in the highest density stands of anywhere in its range. These extraordinary stands coincide with the southern limit of *Thuja plicata*. *Larix lyallii*, a timberline tree, also reaches a southern limit in this unit.

4. South Batholith Division (SB)

The dominant and unifying feature of this division is the southern (Atlanta) lobe of the Idaho Batholith, formed during the Cretaceous in the lee of the continental margin subduction zone and subsequently uplifted. The primary exception is the northeastern section, characterized by the Eocene Challis volcanic rocks. There are also several intrusions of Tertiary granites, including the Sawtooth Range and the Big Horn Crags, which are among the few places in Idaho where granite is sculpted into spectacular peaks and abundant lakes.

Erosional history, including significant Pleistocene glaciation, has resulted in a confusing intertwining of the headwaters of the Salmon, Boise, and Payette rivers. There are no clearly defined ranges, though large montane valleys are a common feature. Substrates are often easily eroded; logging roads cut into steep slopes are subject to collapse, with catastrophic effects on formerly rich salmon streams. Soil formation on the batholith is generally poor; conifer diversity is accordingly much less than in the Clearwater division.

A significant floristic feature is the number of disjunctions from the other great western North American batholith, the Sierra Nevada of California. At least one species, *Eriogonum inerme* (Wats.) Jepson, was probably introduced as miners moved from the Californian gold fields to the newly discovered ones of Idaho, but other examples (e.g., *Lewisia kelloggii* Brandg.) are clearly native. Some of these also occur at intermediate stations, such as Steens Mountain, Oregon, or extend on into the Bitterroot Mountains of Montana.

4a. **Western Salmon River Mountains Unit** (SBws): the granitic western half of the Salmon River Mountains, including Long Valley. This unit generally receives more precipitation than do others in this division. One noteworthy floristic feature is the high diversity of *Saxifraga*, including the Sierran disjuncts *S. bryophora* Gray and *S. tolmiei* T. & G. var. *ledifolia* (Greene) Engl. & Irmsch. On the other hand, *Draba*, common elsewhere in the division, is almost completely absent. *Erythronium grandiflorum* Pursh var. *nudipetalum* (Applegate) Hitchc. is an endemic taxon.

The discontinuous high elevations, especially in the Payette Lakes area, deserve analysis as an example of island biogeography applied to continental situations. Preliminary studies indicate that each peak harbors a different assemblage of subalpine species, with distributions presumably affected by Pleistocene glaciation.

4b. **Eastern Salmon River Mountains Unit** (SBes): the eastern half of the Salmon River Mountains dominated by Challis volcanics. Although the geology has more in common with the East-Central Mountains division to the southeast, the physiographic uniformity with the Idaho Batholith apparently has a greater effect on the floristics. The geologically defined western boundary very roughly approximates that of the Middle Fork of the Salmon River drainage.

Botanical exploration of this unit is challenging due to the often difficult access, even outside the extensive wilderness areas, but definitely rewarding. The Big Horn Crags, for example, are a floristically interesting granitic intrusion into the Challis volcanics. Several eastern range disjunctions have been discovered here, notably *Lewisia columbiana* (Howell) Robins. var. *wallowensis* Hitchc. Portulaceae is particularly well-represented, while the *Saxifraga* diversity that characterizes the granites of the western batholith is essentially absent.

4c. **Boise Mountains Unit** (SBbm): Boise, Danskin, and Soldier mountains, encompassing most of the Boise River drainage. The northern boundary is the South Fork of the Payette River, though an elevational boundary north of the river might be more meaningful.

The Boise Mountains Unit is drier than the West Salmon River Mountains Unit and, as a result, has more open forests, less diversity of tree species, and fewer montane meadows. Fire frequency has probably been a major factor affecting current floristic composition. Noteworthy species that characterize the unit include *Chaenactis evermannii* Greene on decomposed granite slopes, *Corydalis caseana* var. *cusickii* (Wats.) Hitchc. along mountain streams, and *Astragalus adanus* Nels.

4d. **Sawtooth Unit** (SBsw): Sawtooth Range and Sawtooth Valley. The most meaningful boundaries of this unit are difficult to determine, although the core of the Sawtooth Range is dramatically distinct from other units. The boundaries presented here, including granitic portions of adjacent mountains ranges, are decidedly tentative.

The Sawtooths. probably Idaho's best-known mountain range, are glacially sculpted peaks of pink Tertiary granite intruded into the gray Cretaceous Idaho Batholith. The high crest of the Sawtooths capture more rainfall than do the adjacent Boise Mountains Unit to the west, creating environments more mesic than expected in this part of Idaho. The presence of *Menziesia ferruginea* Smith along subalpine creek bottoms is one indication of this.

The Sawtooth Valley is also floristically interesting. As one example, during the Pleistocene large glaciers exited the mountains and flowed into the valley. As these piedmont glaciers retreated, they created habitats in which peatlands formed, which now contain many boreal disjunct species such as *Carex livida* (Wahlenb.) Willd. and *C. buxbaumii* Wahlenb.

5. East-Central Mountains Division (EC)

In contrast to the granitic uniformity of the Idaho Batholith, the geology of east-central Idaho is a complex mixture of Precambrian and Paleozoic marine sediments and metamorphics, Tertiary volcanics, and, in the valleys, Quaternary continental sediments. The mountains are generally higher than elsewhere in Idaho and include the highest elevation, Borah Peak. In the west the named mountain ranges are not particularly distinct, while in the eastern half the parallel ranges and valleys are prominently defined. The seismic activity generally associated with such topography was spectacularly evident in 1983, in the form of the Borah Peak earthquake, 7.3 on the Richter scale.

As a result of both the geologic and topographic diversity, this division is perhaps the most floristically rich section of Idaho. It has therefore been the focus of ongoing botanical exploration by Douglass Henderson and his students at the University of Idaho. Floristic characteristics include the occurrence of several arctic-alpine disjuncts, such as *Papaver kluaense* D. Love. Several Great Plains species also enter Idaho in this division, e.g., *Astragalus bisulcatus* (Hook.) Gray.

5a. **Pioneer/Boulder Unit** (ECpb): Boulder, Pioneer, White Cloud, Smoky, and White Knob mountains. This geological jumble of mountains represents, to a certain extent, the strata that were displaced to the east by the uplift of the Idaho Batholith. Endemic taxa include *Astragalus vexilliflexus* Sheld. var. *nubilus* Barneby in the White Clouds. The Kane Lake area in the Pioneer Mountains has recently gained interest for the number of arctic-alpine disjuncts it harbors (e.g., *Draba fladnizensis* Wulfen) that require more mesic conditions than are generally found in the east-central mountains.

5b. **Borah Unit** (ECbo): Lost River, Lemhi, and Beaverhead (southern Bitterroot) ranges, east to Monida Pass. These mountains represent a northern extension of the Basin and Range Province, isolated by the Snake River Plain. Most of the essential structure of the Basin and Range Province was established during the Miocene, perhaps by back-arc spreading inland from the subduction zone. This unit is largely underlain by carbonate rocks, with small amounts of granite and quartzite.

The mountain ranges are much drier than are those of the adjacent Pioneer/Boulder Unit to the west. Sagebrush-steppe covers the lower slopes, while a relatively thin band of coniferous forest occurs on middle slopes. This unit contains the largest expanse of alpine zone anywhere in Idaho, rich in arctic-alpine disjuncts. The several endemic taxa include *Astragalus amnis-amissi* Barneby and *Cymopterus douglassii* Hartmann & Const.

5c. **East-Central Valleys Unit** (ECev): Big Lost River, Little Lost River, Birch Creek, Pahsimeroi, and Lemhi valleys. The large intermontane valleys that comprise this unit are underlain by deep alluvial deposits in the form of massive fans originating at the base of adjacent mountains. Mountain streams normally sink into the alluvium as they exit the mountains and surface as springs in the center of the valley. Therefore, most of the rivers and creeks flowing down the center of these valleys are spring-fed and are bordered by unique and sometimes extensive wetland communities. Due to the alkaline nature of the parent materials, the aquatic and wetland communities have a basic pH and are quite productive. *Primula alcalina* Cholewa & Henderson is endemic to this unit, occurring in rich fens along with several boreal disjuncts such as *Salix candida* Fluegge and *Lomatogonium rotatum* (L.) Fries.

Upland vegetation is largely dominated by woody *Artemisia* species, including *A. tridentata*, *A. arbuscula* Nutt., *A. nova* A. Nels., and *A. tripartita* Rydb.

5d. **Challis Unit** (ECch): generally unforested hills along the Salmon River from about Clayton to Salmon. This is one of the most arid portions of Idaho, being in the rain shadow of the White Cloud and Sawtooth ranges; the annual precipitation is generally only 18-23 cm (7-9 in).

The sparsely vegetated volcanic outcrops support several endemic taxa, including *Eriogonum verrucosum* Reveal, *Astragalus amblytropis* Barneby, *Oxytropis besseyi* (Rydb.) Blank. var. *salmonensis* Barneby, and *Cryptantha salmonensis* (Nels. & Macbr.) Pays. Several disjunct desert species, such as *Enceliopsis nudicaule* (Gray) A. Nels. and *Langloisia setosissima* (T. & G.) Greene, are also present; these may have used the valleys of the preceding unit as a migration route.

6. Yellowstone Plateau Division (YP)

Included here are the Centennial and Henrys Lake mountains as well as the Idaho portion of the Yellowstone Plateau around Island Park Caldera. The Yellowstone Plateau volcanic field is the current site of the hot spot above a mantle convection plume that may have caused the formation of the Snake River Plain. Rhyolite is therefore a common substrate, in contrast to adjacent areas. Portions of the Centennial and Henrys Lake mountains are comprised of carbonate Paleozoic sediments.

This division is less arid than the adjacent East-Central Mountains Division, having a heavier snowpack and correspondingly more streams and wetlands among coniferous forests. Many of the creeks and rivers are spring-fed, producing rich aquatic macrophyte and peatland communities.

The Yellowstone Plateau Division has floristic affinities with both the Central Rocky Mountains and the Wasatch Unit to the south, but the predominantly volcanic geology contrasts with the Wasatch's carbonate substrates. Several boreal wetland and aquatic species reach their southern limit in this division (e.g., *Lycopodium inundatum* L. and *Scirpus subterminalis* Torr.), while several species typical of the Central Rocky Mountains reach their northern limit (e.g., *Telesonix jamesii* (Torr.) Raf.)

7. Upper Snake River Plain (UP)

One leading hypothesis for the formation of the Snake River Plain is that the volcanic hot spot currently under the Yellowstone Plateau was in southwestern Idaho during the Miocene, and the Snake River Plain represents its track as the continental plate moved westward. Periodic explosive rhyolitic eruptions, dwarfing anything witnessed in historic times, ejected immense quantities of ash into the air. Ashfall Fossil Beds State Historical Park in Nebraska contains skeletons of hundreds of rhinos, horses, and camels, perfectly preserved in a sudden fall of volcanic ash that probably originated in one such eruption from the Snake River Plain.

Volcanic flows subsequent to the explosive eruptions have filled in the downwarp several thousand feet thick. Geological and resultant vegetational diversity is accordingly lower than for other divisions. There are nevertheless some endemic taxa, such as *Astragalus ceramicum* Sheld. var. *apus* Barneby.

7a. **Lava Plains Unit** (UPlp): the vast core with shallow or no soil and, with few exceptions, no surface water. The rivers flowing onto the Snake River Plain from the East-Central Valleys Unit (Big Lost River, Little Lost River, and Birch Creek) soon disappear underground. The primary outlet for the resultant aquifer is the Thousand Springs area over a hundred miles to the southwest along the Snake River. With typical foresight, a major radioactive waste storage area is situated atop this massive aquifer.

The vegetation is a generally monotonous sagebrush flat, punctuated by scattered volcanic buttes and basaltic lava fields, the most recent only a few thousand years old. Such relatively unweathered lava flows are often responsible for most of what floristic diversity does exist, including the extensive and somewhat anomalous stands of *Pinus flexilis* James on the Craters of the Moon and Hells Half Acre lava flows. Kipukas, geological islands in the lava fields, often preserve examples of the vegetation prior to grazing.

Additional diversity is provided by sand dunes, particularly the St. Anthony dunes at the extreme eastern edge where *Oenothera psammophila* (Nels. & Macbr.) W. Wagner et al. grows. In addition, several species commonly found on the Great Plains transcend the Continental Divide and the northern end of this unit, including *Bouteloua gracilis* (H.B.K.) Lag., *Stipa viridula* Trin., and *Astragalus drummondii* Hook.

7b. **Bottomlands Unit** (UPbl): bottomlands of the Snake River and tributaries above Blackfoot, including Teton Basin. The fertile soil developed from the relatively thick alluvial and loess deposits that cover much of this unit has been largely converted to agriculture.

The loess-covered uplands were dominated by woody *Artemisia* species prior to settlement, especially *A. tripartita.* The riparian zones, dominated by *Populus angustifolia* James forests, are still extensive along the Snake River and tributaries.

7c. **Twin Falls Unit** (UPtf): agricultural valleys along the Snake River from about Pocatello to Gooding, including much of the Raft River Valley. This section of the Snake River bore the initial brunt of the Bonneville flood, when Pleistocene Lake Bonneville overflowed at Red Rock Pass about 15,000 years ago. The resultant catastrophic flood cut into the rock lining the Snake River, tumbling columnar basalt segments into boulders called "Melon Gravel." As a result, and in contrast to the Bottomlands Unit, the Snake River is generally confined to a canyon, so that reservoirs and canals are needed to provide water for agriculture.

Previously, the vegetation consisted of *Artemisia tridentata* ssp. *tridentata/Agropyron spicatum* steppe, a habitat type now very rare in Idaho. The most significant floristic elements currently are *Solanum tuberosum* L. and sweet forms of *Beta vulgaris* L.

8. Lower Snake River Plain Division (LP)

Although physiographically the Lower Snake River Plain is an extension of the Upper Snake River Plain (interminably so, to the average driver on Interstate 84), there is a transition near Glenns Ferry into a region that differs in several characteristics from the Upper Snake River Plain. There is less exposed lava, none recent, and more sediments, resulting in substrates with a relatively greater diversity of both texture and pH.

Fish fossils indicate a former drainage to California rather than to the Columbia River. The exact route and any effect this may have had on plant distributions remain undetermined.

8a. **Boise/Payette Valleys Unit** (LPbp): Boise and Payette river valleys and intervening hills from Boise and Emmett to Payette and Vale, Oregon. The original shrub-bunchgrass associations have been largely replaced by agriculture and urbanization, as predicted by William Judson Boone nearly a century ago. As a result, rare taxa associated with this unit are among Idaho's most imminently threatened. Prime examples are *Allium aaseae* Ownbey and *Lepidium montanum* Nutt. var. *papilliferum* Hend. Neither are restricted to the unit but also occur in the transition zones of adjacent units, particularly the Boise Mountains.

The riparian zones have accumulated a number of species more characteristic of the eastern United States. Some species have been deliberately introduced and subsequently become naturalized, such as *Acer saccharinum* L. and *Amorpha fruticosa* L. (and fox squirrels, for a non-botanical example). Others are more problematical, including *Mimulus ringens* L., *Bacopa rotundifolia* (Michx.) Wettst, and *Lindernia dubia* (L.) Pennell. In that several of these occur in the general area where the Oregon Trail crossed the first major riparian corridor below 1000 m elevation west of the Great Plains, it is interesting to speculate that wagon trains may have acted as a dispersal mechanism for some taxa.

8b. **Mountain Home Unit** (LPmh): relatively monotonous sagebrush plateau between the Boise and Snake river terraces. Where not converted to agriculture, the original shrub-steppe habitat has largely been overgrazed and replaced by "improved" rangelands of *Agropyron cristatum* (L.) Gaertn. or *Bromus tectorum* L. and other exotic annual weeds. Although the rare *Lepidium davisii* Rollins can be found on small playas in this unit, it is more common elsewhere.

8c. **Lakebed Unit** (LPlb): exposed lakebed and fluvial sediments of the Idaho Group with interbedded basalts along the Snake River. The sediments were largely deposited during the Miocene (Chalk Hills Formation) and Pliocene (Glenns Ferry Formation) when lakes filled much of the Lower Snake River Plain. The exposed lakebeds are generally ± alkaline and often seleniferous, as indicated by the presence of *Stanleya.* Noteworthy taxa include *Mentzelia torreyi* Gray var. *acerosa* (M. E. Jones) Barneby and *Astragalus nudisiliquus* A. Nels.

Additional diversity is provided by the Bruneau Sand Dunes, which harbor several species seldom found in southwestern Idaho. This includes *Euphorbia ocellata* (Dur. & Hilg.) Millsp. var. *arenicola* (Parish) Jepson, *Psoralea lanceolata* Pursh, and *Enceliopsis nudicaule*.

9. BENNETT HILLS DIVISION (BH)

The (Mount) Bennett Hills consist of a block fault gently rising from the Snake River Plain in the south and dropping abruptly on the north face into the Camas Prairie graben. Both the Bennett Hills and the Camas Prairie would be discordant in adjacent divisions, and are therefore placed together in their own division. The Picabo Hills, Black Butte, and lower Wood River Valley are other relatively discordant elements that are tentatively included at the eastern end of this division.

Most of the Bennett Hills is composed of Miocene Idavada volcanics, particularly silicic tuffs or rhyolite, isolated from the main concentration south of the Snake River Plain (the division is therefore delineated to include a lobe of Idavada volcanics in the Danskin Mountains). The geology is nevertheless relatively diverse, including scablands, basaltic outcrops, and diatomaceous deposits. The most interesting geological phenomena, however, are the bizarrely sculpted outcrops and boulders of the Gooding City of Rocks and other places. It is possible that much of the erosion occurred before the downwarp of the Camas Prairie, when streams draining the Idaho Batholith flowed uninterrupted across the present-day Bennett Hills.

Only the highest elevations at the western end are forested; the vegetation of the rest of the Bennett Hills is a rich mix of bunchgrass, shrubs, subshrubs, and perennial herbs. The floristic distinctiveness of the Bennett Hills was generally not appreciated prior to studies of deer winter range by the Idaho Fish & Game Department in the late 1970's, at which time numerous disjunctions were discovered. Some species, such as *Downingia bacigalupii* Weiler, *Polygonum heterosepalum* Peck & Ownbey, and *Trifolium macrocephalum* (Pursh) Poiret, represent easternmost range extensions of species otherwise west of the Snake River Plains, often with ranges continuing through Oregon to northeastern California. *Artemisia papposa* Blake & Cronq. grows only in the Bennett Hills and Owyhee Uplift. Other species are disjunct from the Weiser Unit and Columbia Plateau, notably *Eriogonum thymoides* and *Erigeron disparipilus* Cronq.

The other regions included in this division have their own floristic novelties. *Haplopappus insecticruris* Henderson is endemic to the Camas Prairie, while *Astragalus oniciformis* Barneby likewise characterizes the Picabo Hills.

10. Owyhee Division (OW)

The Owyhee Division is in large part a plateau dominated by Miocene and Pliocene basalts and rhyolites, including Idavada volcanics, probably associated with the same hot spot that is now under the Yellowstone Plateau. The Owyhee and Bruneau rivers have cut dramatic canyons, whose vertical walls harbor such characteristic species as *Artemisia packardiae* Grimes & Ertter, *Leptodactylon glabrum* Patterson & Yoder-Williams, and *Ivesia baileyi* Wats. var. *beneolens* (Nels. & Macbr.) Ertter; river rafting is to a large extent the only way to botanize long stretches of these canyons.

The boundary with the Snake River Plain is tentatively set at where the alkaline scrub of the Lakebed Unit gives way to sagebrush, about 1660 m (4000 ft) elevation.

10a. **Owyhee Mountains Unit** (OWom): the northwest corner containing the Owyhee Mountains and South Mountain, essentially north of Mud Flat Road. Packard (pers. comm.) describes the geology as "taking an egg-beater to a geology textbook," with a wonderfully diverse flora as a result. Cretaceous granites protrude through the basalts and rhyolites of the division; these granites may be a southward extension of the Idaho Batholith. Curiously, although the granitic mountains are forested, the Ericaceae that are so common on the Idaho Batholith are essentially absent in the Owyhees. *Pinus ponderosa* Dougl., once present, was largely removed during the mining era.

In the extreme northwest edge, a sliver of Oregon's fascinating Succor Creek formation and associated flora enters Idaho. Outcrops of Miocene ash harbor *Trifolium owyheense* Gilkey, *Mentzelia mollis* Peck, *Chaenactis cusickii* Gray, and *Astragalus sterilis* Barneby. This small section could potentially be recognized as a distinct unit, intermediate with the Lakebed Unit of the Lower Snake River Plain.

10b. **Bruneau Plateau Unit** (OWbr): relatively uniform plateau, cut by canyons. *Lepidium davisii* is a noteworthy species of barren flats. Much of what was sagebrush-steppe has been converted to crested wheatgrass rangeland.

10c. **Jarbidge Uplands Unit** (OWjb): south part of Owyhee Plateau, above ca 2300 m (5500 ft) elevation. Though largely sagebrush steppe, this unit is relatively well watered compared to the Bruneau Plateau Unit, with wet meadows such as those at Duck Valley. Northern extensions of the Jarbidge Mountains enter Idaho here, adding an increased floristic diversity. The distribution of *Erigeron latus* (Nels. & Macbr.) Cronq. falls within this unit.

11. Southeastern Mountains Division (SE)

The Basin and Range Province is well developed in southeastern Idaho, with geologically diverse north-south trending ranges separated by generally narrow valleys. Most drainages empty into either the Snake River or the Great Salt Lake, so playa-bottomed valleys such as are common in the Great Basin further south are generally lacking. Higher elevations have sparse conifer forests, with pinyon generally absent from the juniper zone.

All but the western mountains in this division are largely composed of Paleozoic and Mesozoic marine sediments, laid down when this was the western edge of the continent. The eastern half is within the Idaho-Wyoming Thrust Belt, part of the much larger Overthrust Belt favored for oil exploration. Late Mesozoic deformation, perhaps related to the rise of the Idaho Batholith, folded and overturned strata so that older rocks can be found above younger ones.

The climate of southeastern Idaho has a continental influence, in contrast to the semi-maritime climate of southwestern Idaho. As a result, summer thunderstorms are a common phenomenon and precipitation is more evenly distributed throughout the year.

11a. **South Hills Unit** (SEsh): southeast of Twin Falls between Highway 93 and Goose Creek. Although the South Hills are geologically related to the Owyhee Division, floristic affinities are apparently stronger to the east. *Astragalus anserinus* Atwood, Goodrich & Welsh and *Penstemon idahoensis* Atwood & Welsh are endemic species.

11b. **Albion Unit** (SEal): Albion Range and Middle Mountain between Goose Creek and Raft River valleys. Cache Peak is the highest elevation south of the Snake River in Idaho, and Mount Harrison is also quite high. The Albion Range has extremely diverse geology, including probably the oldest rocks in Idaho. *Castilleja christii* N. Holmgren and *Cymopterus davisii* Hartmann are endemic to this unit.

11c. **Pocatello Unit** (SEpc): all the ranges and valleys between the Raft River Valley and the Wasatch Range, including Sublette, Black Pine, Deep Creek, Bannock, Portneuf, and Blackfoot ranges. Holmgren (1972) placed the last three ranges in his Wasatch Mountains Division, with the first three in the Bonneville Basin Section of the Great Basin Division. The relevance of this separation to Idaho floristics deserves closer examination.

11d. **Wasatch Unit** (SEws): more densely forested mountains to the east, including Bear River (= northern extension of Wasatch Range), Aspen, Webster, Caribou, Preuss, and Snake River ranges. This unit receives proportionally more rainfall during the growing season than any other part of Idaho, a situation similar to the central and southern Rocky Mountains. Consequently, deciduous forest communities, dominated by *Populus tremuloides* Michx., are well developed here.

Omernick and Gallant (1986) placed the Bear River Range and the Bear Lake Plateau in the Wasatch/Uintah and Wyoming Basin ecoregions respectively. These need to be examined as potential floristic units worth recognizing in Idaho; *Astragalus jejunus* Wats.and *Cryptantha breviflora* (Osterh.) Pays., for example, enter Idaho only in the Bear Lake Plateau, while several Wasatch Range endemics such as *Penstemon compactus* (Keck) Crosswhite ascend into the Bear River Range from Utah..

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ORIGIN OF COLD DESERT FLORAS IN SOUTHWESTERN IDAHO

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ABSTRACT—Floras are characterized by community dominants. Our flora, with one exception, is very ordinary, composed of community dominants that originated long ago and anywhere but here. Montane forest species are mostly standard issue Arcto-Tertiary, many with Eurasian affinities. Some originated as early as Eocene and virtually none are younger than Miocene. Yellow pine and associates of lower forest margins are of Madro-Tertiary origin or from even earlier forests of southwestern North America and are about the same age as above. Both groups have been in the Northwest since very early time, although they haven't necessarily occupied any one site continuously. Desert shrubs, with exceptions, are Madro-Tertiary derivatives of early Pliocene lines that reached here from mid to late Pliocene or as late as the thermal maximum, about 7000 BP.

We can lay no historical claim to these sluggish, hand-me-down floras from everyone else's evolutionary centers, some lines having not had a real speciation event since the demise of the dinosaurs. Our interesting problems are in the cold desert floras of open xeric spaces.

MICROTHERMAL-INDUCED CHANGES IN COLD DESERT FLORA

Pliocene

Artemisia Section Tridentatae belongs to the Pliocene (although some have put it earlier) and is of northern origin; beyond that its origin is obscure. A circumstantial case can be made for an east central Idaho-southwestern Montana-western Wyoming origin. Like many endemic western genera, it may trace back to general up-warping of the Rocky Mountains at the end of Miocene, continuing throughout Pliocene. The high, cool habitat this uplift created was enough different from previous habitats that pre-adapted species were rare or lacking in the neighboring landscape and for a time it supported few species.

Since early Miocene, cool-adapted circumboreal taxa in boreal North America had been unable to migrate southward through low, relatively warm territory. Up-warping formed a broad highway for boreal lines with practically no competition. Boreal taxa entering this area probably exhibited character release, a general result of removal from competition. This can result with surprising ease, in a radically altered approach to life, leading to formation of new genera. We see this better in the relationship of less modified Pleistocene derivatives of boreal taxa such as subalpine *Smelowskia calycina* (Steph.) C.A.Mev. and the only slightly disguised *Smelowskia* known as *Polyctenium fremontii* (Wats.) Greene of moderately to severely xeric lowland sites.

Artemisia Section Tridentatae is endemic to western North America. The pattern of radiation of what passes for species in this section indicates possible origin in the area indicated above, probably from an herbaceous *Artemisia* migrating southward down the newly risen Rocky Mountains. The ancestral taxon may have been similar to *A. norvegica* Fries, an herbaceous species, somewhat woody at base.

This boreal migrant *Artemisia* may not have been the direct ancestor of Section Tridentatae. Art Holmgren has suggested another western North American endemic, *Sphaeromeria*, the Chicken sage, may be ancestral to the section (Holmgren, Shultz and Lowery 1976), in which case, *Sphaeromeri* would be intermediate between Section Tridentatae and the migrant boreal ancestor. *Sphaeromeria* has been placed in a different genus but looks like sagebrush, smells like sagebrush and probably is sagebrush.

A number of xeric, herbaceous, perennial genera, endemic to intermountain western North America, may have had a similar origin. The adaptive shift from boreal to xeric cold desert so obscured evidence of relationship that phylogenies are determined with difficulty, if at all.

Pleistocene

Mud Flat Flora

The mud flat flora includes species now growing on thin soil over basalt; sites wet in early spring and bone dry the rest of the year. Not only is soil saturated with water most of the growing season, it tends to be clayey. Roots of Mud Flat species appear to be functioning in fairly anaerobic conditions.

Distribution radiates from Mud Flat to Sunflower Flat in Elko County, the Little Owyhee country in Malheur County, north through the Bennett Hills and Camas Prairie, with a few species extending to the Sawtooth Valley, or west along the Boise Front and Freezeout area, and north barely into Washington. They are not typically species of lower elevations, usually being found 1666 m (4000 ft) or above. They bloom March to May and into July at high elevations. Since this is mud season, they are poorly known.

These are possibly remnants of local tundra-like floras that occurred at full glacial periods at slightly lower elevations than tundra or in the cold but dry period immediately following full glacial. They probably evolved under the same general climatic conditions but not all species had a common history, having been derived from mostly local species in different areas. They may be products of different glacial periods but all passed through the final glacial period. They do not all occupy any one area today, most, but not all are found at Mud Flat, Nevada. Hence, this is probably not a flora in the true sense of the word.

Most species were derived from western North American species of boreal origin, some are derived directly from boreal species. Large ranges suggest that the first two of the following selected mud flat species may be products of earlier Pleistocene glacial periods.

Ranunculus andersonii Gray is the only representative of its section in lower western North America. A similar species grows in boreal Europe and Alaska. Its range today is the Great Basin, north into drier mountains of central Idaho. This is the most extensive range of the mud flat species. There is little indication of its area of origin, it may have been in the region of dry central Idaho mountains.

Viola beckwithii T&G may have originated between the Great Basin proper and the Oregon portion of the Great Basin. It merges into *V. trinervata* Howell of north central Oregon and central Washington. Related species are distributed along the east slope of the Cascades. Phylogeny of this group is unknown to me. Its range is more extensive than ranges of most other mud flat species but is more western and does not equal that of R. andersonii.

Primula cusickiana Gray and *Artemisia papposa* Blake & Cronq. probably originated in or near the Mud Flat-Camas Prairie region. *P. cusickiana* appears to be a miniaturized *P. parryii* Gray of the Rocky Mountains while Cronquist suggests *A. papposa* may have affinities with *A. norvegica* (Cronquist 1955:66-7). Both suspected progenitors are either directly or indirectly of boreal origin. The *Primula* is highly discontinuous over a fairly large range north of the Snake River and the Mud Flat region, the *Artemisia* has not spread beyond the probable area of origin. *A. papposa* is sharply distinct from anything else on earth; *P. cusickiana* is involved in taxonomic problems above and below the species level, as is typical of species of this origin that have expanded their range beyond the area of origin.

These species, coming out of the cold dry climates of the immediate post-glacial period, can be recognized because they have not spread beyond their distinctive habitat or occur in forms with some degree of modification on other habitats. Probably other species of similar origin have adapted to 'normal' soils but we have little clue to their origin. This may include many species centering in xeric areas north of the Great Basin and in xeric outcrops at high altitudes. Species of such common genera as Trifolium, Astragalus, Draba, and Lepidium are suspected.

Pleistocene loss of Macrothermal Pliocene Species in Southern Idaho

At the end of Pliocene, the landscape gave a mighty heave and long east-west tending humps rose up along the southern Idaho border extending west into Oregon. The Snake River was rerouted into the Columbia system through Hell's Canyon. This uplift was apparently tundra-like during pluvial periods and even permafrost has been suggested, at about 1666 m (4000 ft). Conventional wisdom says that when the cold came, temperate plants migrated south. Montane plants could migrate south but the only possible migration route for macrothermal lowland taxa was northward through Hell's Canyon, in a direction counter to climatic change and so narrow it offered a very inadequate refugium. The geography of southern Idaho is poorly suited for retention of macrothermal lowland species under conditions of oscillating climate, consequently surviving pre-Pleistocene taxa tend to have wide ecological tolerance. Many present desert species, e.g. *Eriogonum ovalifolium* Nutt., have varieties growing with *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle at high altitudes and it is not unusual to find single varieties that grow in any *Artemisia tridentata* community, no matter what the variety of *A. tridentata* or habitat.

MACROTHERMAL-INDUCED CHANGES IN COLD DESERT FLORA

Immigration of Great Basin species

At times during the post-glacial period, temperatures have exceeded those prevailing today, with maximum temperatures about 7000 years BP. Blue Mountain Pass in southern Malheur County and the Rogerson area in Twin Falls County have been important gateways to the Lower Snake River Plains, allowing Great Basin species to cross the low hump between there and the Great Basin, presumably during periods of increased temperature. Species from the summer-dry Lahontan side of the Great Basin are abundant in the summer-dry Snake River Plains, but species from the summer-wet Bonnevillian side are almost entirely excluded west of Twin Falls County.

Great Basin taxa are concentrated below 3000 feet in the Snake River Plains but may go much higher, and tend to be confined to desperately barren spots. They tend to be highly disjunct within the Snake River Plains and typically show large disjunctions between the Snake River Plains and their main range in the Great Basin. Many Great Basin taxa in the Snake River Plains appear to be the classic picture of plants with narrow ecological tolerance that have failed to become established.

Enceliopsis nudicaulis (Gray) A.Nels. has this typical distribution. However, *E. nudicaulis* in full bloom on a mossy, north facing, sheer rock face dripping with water, the attractive scene framed by Douglas fir on either side, shakes one's faith in this easy explanation. Narrow ecological limits are probably not its problem. One is left with the often used but blatantly unscientific "it lacks competitive ability." These Great Basin species probably did migrate into the area during the period of maximum temperature, but increased temperature may have been only an indirect factor inducing migration. In the Great Basin, there is space between shrubs and little undergrowth; in the Snake River Plains the canopy of one shrub abuts on the canopy of the next, and if the range hasn't been too badly abused, spaces are filled with grasses and forbs. This is especially true of the low hump that must be crossed from the Great Basin to the Snake River Plains. High temperatures for a sustained period would have reduced vegetative cover and thus reduced competition for Great Basin species, unadapted for life in a heavily vegetated area.

Post-glacial Speciation

Outcrops of a Miocene ash cut a swath across Malheur County and southern Idaho. This ash is incompatible with life during normal years except for 15 taxa, all entirely endemic to the ash. Other than these taxa, the ash is bare. Only in years of exceptional rainfall will cheat grass attempt these sites. The Owyhee Uplift and adjacent Snake River Plains contain about 1000 taxa, so ash pile endemics are a good one percent of the flora, even though all are rare and some are in the process of being federally listed as threatened or endangered.

The ash has decayed under different environments, forming different decay products. Some ash piles are heavily clayey. Ten of the endemic taxa grow on this clayey ash.

Phenology of the 10 taxa of clay ash indicates a probable origin in the warmer, later part of the Pleistocene. Species affinities are various but heavily slanted toward Great Basin progenitors, *Mentzellia torreyi* Gray var. *acerosa* (M.E.Jones) Barneby is certainly a relict of range expansion of Great Basin taxa during the thermal maximum about 7000 years ago, and six others are probably of that origin. *Astragalus kentrophyta* Gray var. *jessicae* (M.E.Peck) Barneby is a variety of high montane species, itself probably a product of speciation in the cold dry period following full glacial. *Astragalus cusickii* Gray var. *packardiae* Barneby is a species of the same probable origin. Chaenactis cusickii Gray belongs to a genus of regional derivation (Mooring 1980:1315-7). An earlier origin can not be ruled out in all cases, but for the most part, the origin of these taxa was very near in time.

That 1% of the taxa in a flora could be produced on one insignificant habitat in something like 7000 years is unsettling; yet probably no exceptional evolutionary mechanisms were involved. *Mentzellia mollis* M.E.Peck is a tetraploid, a common evolutionary tactic in that genus. Catastrophic selection and character release, requiring no genetic mechanisms, are sufficient to account for origins of other taxa by just doing what comes naturally.

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FLORA OF EAST CENTRAL IDAHO: THE PROJECT

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ABSTRACT—Prior to 1973 the flora of east central Idaho had been studied only superficially. In that year a long-term, intensive floristic survey was initiated with collections made from all habitats from low elevation riparian and shrub-steppe to the highest alpine summits in much of Butte, Clark, Custer, Fremont, northwestern Jefferson, and Lemhi counties. Many species not previously known for Idaho were collected, as well as some new for the Northern Rockies, and a few new to science. A current assessment of the flora of east central Idaho includes 976 vascular plant species distributed among 339 genera and 80 families. Phytogeographic affinities of the flora are varied: species contributing to the lower elevation shrub-steppe are largely from the Intermountain/Great Basin flora with 21% endemism; species of the broad forested zone above shrub-steppe include mainly Rocky Mountain, Pacific Northwest/Northern Rockies, and Boreal affinities with 11% endemism; above upper timberline the alpine flora has affinities with Arctic, Boreal, western North America, Northern Rockies, central to southern Rockies, Intermountain/Great Basin, and includes 21% endemics. The endemic component is considerably higher than that reported for most Rocky Mountain floras and is probably the result of several factors present in east central Idaho, including varied climates and precipitation patterns, extreme topographic relief and substrate diversity, and the mixing of several major floras in the region.

INTRODUCTION

That part of Idaho generally east of the Middle Fork of the Salmon River and the Sawtooth Range to the Montana border and south to the northern border of the Snake River Plain is often referred to as east central (Fig. 1). The area is dominated by several northwest-southeast-trending mountain ranges and their intervening valleys. Topographic relief here is pronounced with numerous summits rising abruptly 1,800 m or more from the valley floors. Major drainages include the Main and East forks of the Salmon River, the Wood, Big and Little Lost, Pahsimeroi, and Lemhi rivers, and Birch Creek. Other important features include the Sawtooth, Lost River, and Lemhi ranges, the Salmon River, Pioneer, and Beaverhead mountains, and the White Cloud Peaks. The region also includes Idaho's highest peak, Mt. Borah, in the Lost River Range.

The region is also diverse in geologic features. Mixed metamorphics, granites of the Idaho Batholith, Precambrian Superbelt rocks, and various carbonate-rich sediments are frequently overlain with deposits of the Challis Volcanics, not infrequently with all of these in close juxtaposition (Ross 1947, 1961; Nelson and Ross 1968; Skipp and Hait 1977; Dover 1961; Wust and Link 1988; and Moye et al. 1988).

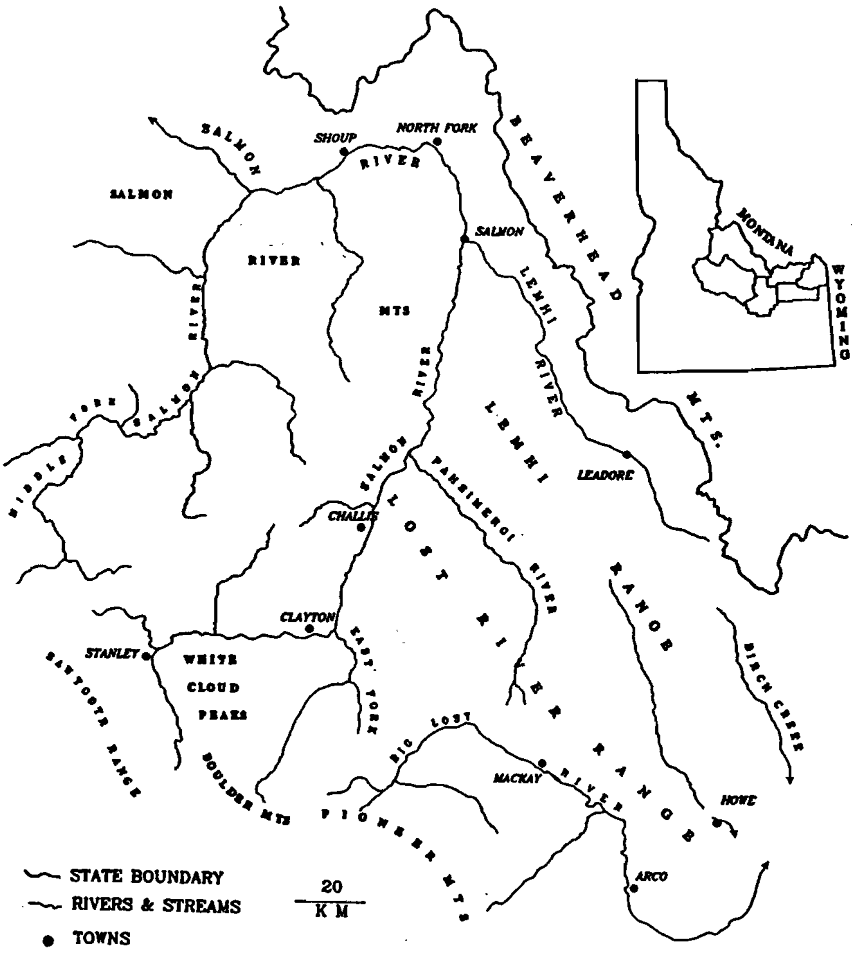

Figure 1. Map of study area showing location of major geographic features. Upper right shows location of study area in Idaho.

East central Idaho is also a region of climatic transition. The northern parts are moderately influenced by a Pacific maritime climate with its typical summer droughts. A Great Basin climate strongly influences the southern region where the mountains subside into the Snake River Plain, and summer, moisture-laden air from the Gulf of Mexico is not infrequent in the southeastern parts of this region (Ross and Savage 1967; Rice 1974). As is typical of continental areas, summer and winter temperatures can be extreme. In general, this is an area of low humidity with cold, relatively dry winters, and warm summers with frequent midday thundershowers.

The vegetation is typical of a north-temperate, continental, mountainous region. Valley bottoms generally support a shrub-steppe dominated by the shrub genera *Artemisia, Chrysothamnus*, and *Atriplex*, and the pooid genera *Elymus, Poa*, and *Stipa*. Riparian vegetation generally includes *Salix, Populus*, and *Betula*. Lower montane slopes support temperate coniferous forests of Pinus ponderosa, or in its absence (in the south and east), *Pseudotsuga menziesii*. The latter species is frequently accompanied by *Pinus flexilis* and *Pinus contorta*. Higher-elevation forests tend to be dominated by *Abies laslocarpa* and *Picea engelmannii*. In many places an upper timberline is well-developed and can support both previous taxa in addition to *Pinus albicaulis*. In the drier, southern parts of the ranges, *Abies lasiocarpa* is absent; there, upper timberline is often composed of *Picea engelmannii* on north aspects and *Pinus flexilis* and *Pinus albicaulis* on southerly exposures. Upper timberline occurs mostly between 2,990 and 3,200 m elevation. Above this, alpine vegetation can be composed of a few species scattered across unstable talus slopes and near-vertical rock, or extensive closed communities developed on gentle, rolling topography.

BOTANICAL HISTORY

Prior to 1973 the flora of east central Idaho had received little attention from plant collectors. The first collections along the southern edge of the region were made by Nathaniel Wyeth in 1833, to be examined and named by Thomas Nuttall the following year. Nuttall passed through part of the region in 1834 on a trip west from Fort Hall, possibly attempting to traverse the Pioneer Mountains, and made perhaps the first collections from east central Idaho including species of *Artemisia, Aster, Erigeron*, and *Haplopappus suffruticosus* (*Macronema s.*) (McKelvey 1955).

From his station in Moscow as curator of the newly-formed University of Idaho Herbarium, L. F. Henderson entered part of east central Idaho on a collecting expedition in the late 1890's. Although his collections were not extensive, he may have been the first botanist to encounter some of the endemic taxa (e.g., *Ribes hendersonii* Hitchc.). It was not until just after the turn of the century, however, that significant collections were made in the region.

Aven Nelson, curator of the Rocky Mountain Herbarium, and his students J. F. Macbride and E. Payson collected extensively across southern Idaho and on occasion, ventured north to collect in parts of east central Idaho (Cronquist et al. 1972). From Idaho State University in Pocatello, Ray J. Davis collected extensively in Idaho between the 1930's and 1940's, ultimately publishing the only flora for the state, ***Flora of Idaho***, in 1952 (Cronquist et al. 1972). Although Davis' collections were extensive, east central Idaho was only superficially represented in his herbarium. Other collectors active in the region at the same time were Dwight Ripley and Rupert Barneby, discovering some of east central Idaho's endemics such as *Astragalus amnis-amissi* Barneby (Cronquist et al. 1972). Also during the 1940's and 50's, C. Leo Hitchcock and Clarence Muhlick from the University of Washington Herbarium were collecting intensively in Montana and Idaho. Their intentions were to include east central Idaho as part of the intensive collecting, but logistics and foul weather limited their visits (Hitchcock pers. comm.). John H. Christ, working for the Soil Conservation Service, made extensive collections from Idaho (Cronquist et al. 1972) but only superficial coverage was given to the eastern part of the state. Additional botanists have visited the region, mostly seeking out plants of their respective specialties. Even though many botanists had visited the region, knowledge of the flora of east central Idaho remained superficial. This last thought was communicated to me by C. L. Hitchcock during a field trip through east central Idaho in 1969.

METHODS

An intensive floristic effort over an area the size of east central Idaho demands considerable planning and logistic support. Base camps of operations were established each field season between 1973 and 1987. The mountainous areas remain relatively inaccessible with few trails and fewer roads, so much of the collection was done on foot or via primitive roads. Operations for each season were begun in late May or early June and proceeded from low to high elevations as the flowering season progressed. Air photos, geologic maps and reports, and U.S.G.S. topographic maps were used to identify both common and potentially unusual habitats. Efforts were made to collect in all habitats with a different area covered each season. All vascular plant groups were included in the collections. Specimens were gathered, sealed in inflatable plastic bags, and transported to base camp in white plastic garbage bags. There the specimens were pressed and dried in a standard plant press (12" x 18") then transported to the University of Idaho Herbarium where identifications were confirmed or specimens sent to experts for confirmation. Duplicate specimens in sets of 2-30 were prepared for each collection number and have been used for exchange with other herbaria across North America and Eurasia. All original specimens have been deposited in the University of Idaho Herbarium (ID).

RESULTS

To date much of the region has been collected intensively although a few small areas still remain to be investigated. The current assessment of the vascular plant flora of east central Idaho includes 976 species distributed unevenly in 339 genera and 80 families. The flora contains only one endemic genus, *Kelseya* (Rosaceae), but no endemic families. The number of species (not infraspecific taxa) endemic to east central Idaho is only 21 and represents about 2% of the flora. Adding an additional 14 infraspecific endemics accounts for another 1.4%, for a combined specific/infraspecific endemic component of 3.4%. These are taxa endemic only to east central Idaho, but the flora of this region is a natural assemblage of plants extending eastward into adjacent Montana and northwestern Wyoming, and it includes numerous additional endemics that are also present in east central Idaho. The endemic component of this tri-state flora includes 74 species (7.6%) that are present in east central Idaho and also in adjacent southwestern Montana and northwestern Wyoming, which is nearly double the endemic percent of most Rocky Mountain floras (cf. Johnson and Billings 1962; Komárková 1979; Hartman and Rottman 1985).

A phytogeographic analysis, based on the three major vegetations in east central Idaho, provides an additional perspective on endemism. These three vegetations (shrub-steppe, coniferous forest, and alpine) include 881 species (90%) of the total known species in east central Idaho. Taxa included in this analysis are those **predominantly** occurring in one of the three vegetations. Species with broad ecologic amplitude (e.g., *Achillea millefolium*, *Lesquerella carinata*) are not included. Of the 272 species found in the shrub steppe, affinities are as expected — predominantly Great Basin. Endemic species number 57 or 21% of the shrub-steppe flora. Coniferous forests include 323 species with phytogeographic affinities ranging from Circumboreal to endemic but with the major component typically Rocky Mountain. Thirty-six species or 11% are endemic in the flora of this broadly-defined vegetation.

Finally, the alpine vegetation of east central Idaho contains 286 species with phytogeographic affinities from Holarctic and Circumboreal to endemic, and, unlike the lower vegetations, with fairly even distribution in all categories. Perhaps initially surprising is the endemic count of 60 species (21%), clearly much higher than average (ca. 4%) reported for other Rocky Mountain alpine floras (Johnson and Billings 1962; Komárková 1979; Hartman and Rottman 1985), and higher than the 16% reported by Major and Taylor (1977) or 13.5% reported by Stebbins (1982) for endemism in the Sierran alpine of California.

NEW SPECIES AND RANGE EXTENSIONS

That east central Idaho had not been thoroughly collected by previous botanists is documented by the wealth of new state and regional records encountered since this project was initiated. Numerous native species not previously known for Idaho were reported (Henderson 1978; Henderson et al. 1981; Goodrich et al. 1983; Cholewa and Henderson 1983; Caicco et al. 1983; Brunsfeld et al. 1983; Lackschewitz et al. 1983; and Cholewa and Henderson 1984). Perhaps even more convincing are the additional endemics discovered since 1973 that are new to science including *Draba hitchcockii* Rollins, *Draba trichocarpa* Rollins, *Thlaspi aileeniae* Rollins, *Eriogonum meledonum* Reveal, *Primula alcalina* Cholewa and Henderson, *Agoseris lackschewitzii* Henderson and Moseley, *Erigeron salmonensis* Brunsfeld and Nesom, and a new species of *Oryzopsis* discovered by the author and currently being described by Michael Curto.

SUMMARY AND DISCUSSION

The vascular flora of east central Idaho is now known to include 976 species, which is approximately 37% of the total flora of Idaho, indicating relatively high diversity within this region.

The floristic diversity in east central Idaho is no doubt a function of numerous interdependent factors. The region is climatically transitional from Pacific Maritime to more continental conditions. Moisture gradients are pronounced from north to south and from west to east, allowing species with rather different moisture requirements to be closely juxtaposed. This is also an area of floristic intermingling (both past and present) with elements from the Great Plains flora entering on the east (e.g., *Bouteloua gracilis* and *Astragalus gilviflorus*), the central-southern Rocky Mountain flora (e.g., *Picea pungens*), species typical of Northern Rockies and Pacific Northwest (e.g., *Xerophyllum tenax* and *Larix lyallii*), and the Intermountain/Great Basin floras (e.g., *Enceliopsis nudicaulis*). Also present are species of Arctic and Boreal affinities in the subalpine forests and alpine turfs and fell-fields. Superimpose these biotic factors on a landscape of extremes in topographic relief and substrate diversity and we have many of the elements present that are thought to promote both floristic diversity and endemism (Raven 1964, 1977; Stebbins and Major 1965; Kruckeberg 1969, 1986; Kruckeberg and Rabinowitz 1985).

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RARE PLANT CONSERVATION IN IDAHO

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ABSTRACT—Rare plant conservation in Idaho is discussed in four parts. First, I place rare plant conservation activity in an historical context by reviewing major events from the turn of the century to the present. Using this as background, I then review the current status of Idaho's rare flora, followed by a discussion of rare plant conservation activities of the major federal and state agencies and a private organization. Finally, I look ahead and review six areas that need increased emphasis and funding in the future, so that rare plant conservation can be accomplished in an efficient and effective manner.

HISTORICAL PERSPECTIVE

John Leiberg was probably the first botanist to recognize the occurrence of a rare plant in Idaho. In his survey of the old Bitterroot Forest Reserve for the U.S. Geological Survey, Leiberg (1900) reported populations of *Cornus nuttallii* Aud. along the lower Lochsa and Selway rivers in north-central Idaho. He noted: "That the species should occur in the basins of the Clearwater drainage is remarkable. Its home at this latitude is in the Cascades and, so far as is known, it does not grow at any intermediate station." It's amazing how accurate this statement was, considering the inaccessibility of the region at the time. In the intervening 92 years, no intermediate stations have been found, and the localized population of *C. nuttallii* in Clearwater Basin is a conspicuous and rare element of Idaho's biological heritage.

From the time Lewis and Clark collected the first plant specimens in Idaho in 1803, up through the 1960s, the floristic exploration and taxonomic treatment of Idaho's flora played a major role in field botany. That analysis continues today, as new species and new floristic records for the state are discovered every year. Although interesting phytogeographic patterns were noted prior to the 1960s, such as the concentration of coastal disjuncts in the Clearwater Basin (Daubenmire 1952), and narrow endemism of certain taxa (e.g., Hitchcock and Thompson 1945), the conservation of rare plants was not an important aspect of botanical and ecological study in Idaho.

The conservation outlook began to change in the 1960s. First, in the early to mid-1960s, a state law was passed to protect wildflowers and shrubs along highways (**Idaho Code** 18-3911). Under the leadership of the Idaho State Federation of Garden Clubs, Inc., this law was one of the first native plant protection acts in the country (L. Pethel, Kamiah, ID, pers. comm., 1986). Aside from highway beautification, the impacts of habitat destruction on Idaho's flora was also beginning to be noticed about this time. For example, Marion Ownbey (1969) commented on the effect of large-scale land conversion on a conspicuous Palouse Prairie endemic, stating: "Except along the eastern border of its range, *Calochortus nitidus* grows in potential farm land. As a consequence, it has become one of the rarest of our species of *Calochortus*. In the last 25 years, perhaps half its known populations - none very large - have been destroyed."

Also in the late-1960s, Fred Johnson, University of Idaho, became interested in the ecology of forest ecosystems in northern Idaho that harbored numerous plants disjunct from coastal regions of the Pacific Northwest (Johnson 1968). He directed three graduate students who studied the ecology of these unique communities and catalogued many of the disjunct and endemic taxa associated with them (Roper 1970; Steele 1971; Graf 1974). Other areas of the state containing high numbers of disjunct and endemic taxa were also beginning to be catalogued at this time, including the east-central portion by Doug Henderson, University of Idaho, and the western Snake River Plain and Owyhee Plateau by Patricia Packard, College of Idaho.

In 1974, the Idaho Natural Areas Council organized the Rare and Endangered Plants Technical Committee, which began its legacy of rare plant conservation by producing the first lists of rare, threatened, and endangered plants in the state (Henderson 1974; Johnson and Steele 1974).

The Endangered Species Act (ESA) of 1973 was the first federal law intended to preserve vulnerable plants in this country. Although somewhat weak in its protection of plants, the ESA provided much of the impetus for later rare plant protection activities in Idaho. The Smithsonian Institution was given the task of developing the first list of Endangered and Threatened plants in the United States. In August, 1974, they convened a workshop of well-known plant taxonomists from around the country, which resulted in lists of proposed Endangered (**Federal Register** 16 June 1976) and Threatened (**Federal Register** 1 July 1975) plant taxa. These lists contained 68 taxa known to occur in Idaho. No Idaho botanist contributed to the Smithsonian workshop, however, and their list included many Idaho species that did not warrant federal protection (Henderson et al. 1977). In what amounted to an Idaho rebuttal, the Rare and Endangered Plants Technical Committee evaluated these 68 taxa in a publication that became know as the Redbook (Henderson et al. 1977). They removed 14 species from the list and rearranged the degree of endangerment on a few others.

The first Idaho plant to be listed under the ESA was *Mirabilis macfarlanei*, which was listed as Endangered on 26 October 1979 (U.S. Fish and Wildlife Service 1979). The next year *Astragalus yoder-williamsii* became the first plant in the country declared Endangered under the emergency listing procedures of the ESA, due largely to mining threats at the type locality in Nevada (**Federal Register** 13 August 1980). The emergency listing lasted for about six months, until it expired on 15 April 1981, due largely to a decreased threat to the Nevada population.

The ESA was the impetus needed for the major land-managing agencies in Idaho to begin conducting rare plant inventories in the late 1970's. Several BLM Districts, including the Boise (Rosentreter 1980), Burley (Packard et al. 1979), Coeur d'Alene (Heidel 1979; Hurd 1980), Idaho Falls (Anderson and Henderson 1978; Reese and Henderson 1980) and Shoshone (Eidemiller 1977a; 1977b; Harrison 1981), all completed initial field inventories for rare taxa. Field investigations of Forest Service land during this period included the Nez Perce and Clearwater national forests (Johnson and Crawford 1978; Crawford 1980), Hells Canyon National Recreation Area (Johnson and Mattson 1978), Targhee National Forest (Douglass et al. 1978; Holte and Whitehead 1978), Caribou National Forest (Dieffenbach n.d.; Shultz and Shultz 1978), Sawtooth National Forest (Shultz 1980), several southern Idaho forests (Phillips 1976), and especially the Challis National Forest, where a four-year agreement between that Forest and the University of Idaho Herbarium led to a relatively thorough investigation of rare plant taxa in this floristically diverse region of Idaho (Henderson 1983).

As a result of this increased activity and the inadequate treatment of Idaho's rare flora by the Smithsonian lists, the Rare and Endangered Plants Technical Committee produced a second, much larger Redbook in 1981 (Rare and Endangered Plants Technical Committee

1981). In the second Redbook they evaluated about 460 vascular taxa, including 106 globally rare taxa for potential federal protection, 245 taxa rare within Idaho for possible protection at the state level, and 108 taxa that were rejected from consideration because they were common and/or lacked threats to their existence. This edition of the Redbook was updated in 1983, with status changes and the addition of about 15 more taxa to the state and federal lists (Rare and Endangered Plants Technical Committee 1983).

It should be noted that the members of the Rare and Endangered Plants Technical Committee of the Idaho Natural Areas Council made an enormous contribution to the understanding of Idaho's flora and their work formed the foundation for all subsequent rare plant conservation activities in Idaho...and they did all this largely as volunteers. The original members of the committee consisted of Bob Steele, U.S. Forest Service, Douglass Henderson, University of Idaho, Fred Johnson, University of Idaho, and Patricia Packard, College of Idaho. They were later joined by Steve Brunsfeld, University of Idaho, and Karl Holte, Idaho State University.

In 1984, the Idaho Natural Heritage Program (now called the Conservation Data Center) was established under a cooperative agreement between The Nature Conservancy and the Idaho Department of Fish and Game. We inherited nearly two decades worth of collective rare plant knowledge, largely from personal experiences and the extensive data compilation of the Rare and Endangered Plants Technical Committee. This information was incorporated into our map, manual, and computerized data bases, providing continuity with standardized methodologies and a full-time botanist to what had been largely a volunteer effort. We are now the central repository for nearly all rare plant information in the state, our goal being to maximize the use of this data in the conservation of biological diversity in Idaho.

STATUS OF IDAHO'S RARE FLORA

With this as a background, I'd like to review the current status of Idaho's rare flora, which has been discussed annually since 1984, at the Idaho Rare Plant Conference. Initiated by the U.S. Fish and Wildlife Service, but now organized by the Idaho Native Plant Society (INPS), the conference is held the second week in February each year. In 1992, over 70 professional and amateur botanists gathered in Boise to assess the conservation status of 349 vascular and nonvascular plants and lichens (Idaho Native Plant Society 1992). With an expanding number of field botanists working around the state, our knowledge of the distribution, abundance, and threats to Idaho's flora is increasing at a rapid rate. The object of this annual assessment, therefore, is to keep the rare plant lists as dynamic as possible to reflect current knowledge.

Idaho's rare flora is classified into six major categories based on distribution, abundance and threats. Below are some statistics relating to our rare vascular and nonvascular flora resulting from the 1992 Idaho Rare Plant Conference (Idaho Native Plant Society 1992), including a corresponding definition of each category and number of taxa so classified:

FEDERAL (Listed and Candidate taxa under ESA, defined below) 48

STATE (INPS Categories, with no legal protection)

Priority 1 (taxa in danger of becoming extirpated from Idaho in the foreseeable future if identifiable factors contributing to their decline continue to operate) 54

Priority 2 (taxa likely to be classified as Priority 1 within the foreseeable future in Idaho, if factors contributing to their population decline or habitat degradation or loss continue) 65

Sensitive (taxa with small populations or localized distributions within Idaho that presently do not meet criteria for classification as Priority 1 or 2, but whose populations and habitats may be jeopardized without active management or removal of threats) 69

Monitor (taxa that are common within a limited range as well as those taxa which are uncommon but have no identifiable threats) 49

Historical/Extirpated (taxa which are known in Idaho only from historical, ca. pre-1920 records or are considered extirpated from the state) 9

Review (taxa which may be of conservation concern in Idaho, but for which we have insufficient data upon which to base a recommendation regarding their appropriate classification) 55

TOTAL 349

Douglass Henderson estimates that Idaho's vascular flora consists of about 3,000 taxa (D. Henderson, University of Idaho, pers. comm., 1992), meaning about 10% of state's vascular flora is rare to some degree. Included on this list are narrow endemics that are globally rare and/or threatened, peripherals and disjuncts that are more common elsewhere, and widely distributed taxa that are uncommon throughout their range. Following are selected examples used to illustrate the status of Idaho's rare flora, ranging from those species that are rare and secure to those that are rare and declining and even imminently threatened with extinction.

First is an example of a rare, narrow endemic that occurs in a relatively secure habitat. *Erigeron salmonensis* Brunsfeld and Nesom is known from only one population of less than 1,000 individuals in the Salmon River Canyon, Lemhi County, but it appears stable and not imminently threatened at this time (Brunsfeld and Nesom 1989; Moseley 1989). Although this and other narrow endemics, such as *Castilleja christii* N. Holmgren (Holmgren 1973) and *Douglasia idahoensis* Henderson (Henderson 1981; Moseley 1990), all appear to be relatively stable and not imminently threatened at present, they are never-the-less vulnerable to incremental degradation or destruction of their habitat by human development. Rare species such as these need comprehensive conservation strategies in place that, at a minimum, establish monitoring programs for early detection of downward population and habitat trends.

Contrast this scenario with species that were once widespread but are now imminently threatened with a severe loss of genetic diversity and evolutionary potential and possibly even extinction. The status of three Palouse endemics is one of the most ominous examples in Idaho. *Aster jessicae* Piper, *Haplopappus liatriformis* (Greene) St. John, and *Silene spaldingii* Wats. are largely endemic to the Palouse Prairie of Idaho and Washington; S. spaldingii also occurs in the grasslands of eastern Oregon and northwestern Montana. All three species are imperiled throughout their range (Gamon 1991; Lorain 1991a; 1991b). Much of their native deep-soil habitats have long-ago been converted from bunchgrass prairie to annual croplands. Extant populations of these species are relegated to small prairie remnants, such as corners of fields, road right-of-ways, or forest-grassland borders. The long-term viability of nearly all remaining populations is questionable due to their highly fragmented nature.

While these habitat alterations are obvious and imminent, subtle changes are taking place in ecosystems due to human intervention that may also be responsible for declines in rare plant populations in Idaho. Two examples follow.

The first concerns *Penstemon lemhiensis* (Keck) Keck and Cronq., endemic to Lemhi County, Idaho, and adjacent Montana, where its preferred habitat is bare-soil microsites in *Artemisia*-steppe and *Pinus ponderosa* Dougl. woodlands. In a status survey for this species, Moseley et al. (1990) found that most of the nearly 90 Idaho populations consisted of fewer than 50 plants and that microsites suitable for establishment were rare in most occupied communities. We observed that *P. lemhiensis* populations were more vigorous in habitats where disturbance regimes leave bare-soil microsites and were very small in undisturbed communities that begin to close and leave very few suitable microsites as vegetative succession proceeds towards advanced stages (Moseley et al. 1990). Ramstetter (1983) observed a similar pattern in Montana. Prior to large-scale suppression efforts, fire was an important ecosystem process responsible for creating suitable microsites. Fire history studies within *P. lemhiensis* habitat reveal that frequent surface fires predominated prior to 1935, with fires occurring every four years on one study area (Barrett and Kilgore 1985; Barrett 1988). The most vigorous population we observed, in terms of both individual plant growth and population numbers and density, occurred in the Long Tom Complex Fire, which burned in 1986 (Moseley et al. 1990).

The second example involves loss of biotic diversity in wetland and aquatic communities at Hager Lake in Bonner County. The floating sphagnum mat on the south side of the lake is habitat to seven rare plant taxa, in addition to another, *Carex leptalea* Wahl., that is possibly extirpated (Bursik 1992). The ecosystem harboring these rare boreal disjuncts is itself rare in Idaho, being at the southern limit of its distribution. John Rumely conducted a quantitative analysis of the aquatic and wetland communities at Hager Lake in the early 1950s (Rumely 1956).

Although it was probably not his intention at the time, Rumely's data has become an important baseline from which we can measure nearly four decades of change in the system. Recent studies and observations at Hager Lake reveal that some dramatic changes have taken place in the intervening 40 years. Rob Bursik, formerly of University of Idaho Herbarium and now with the Conservation Data Center, conducted floristic studies of the bog (Bursik 1990; 1992) and Fred Rabe, University of Idaho, studied surface water chemistries (Rabe et al. 1990). Rumely (1956) reported *Carex leptalea, Ranunculus uncinatus* D. Don, *R. aquatilis* L., and *Potamogeton amplifolius* Tuckerman in his checklist of the flora of the area. Bursik found no populations of these species during intensive searches between 1987 and 1991. Rumely also noted that *Brasenia schreberi* Gmel. had 34% coverage and 100% frequency in his plots in the outer littoral zone of the lake. In 1991, Bursik found only five widely scattered plants. Surface water chemistry changes are equally striking. Rumely noted the calcium concentration to be 11.6 mg/l and magnesium ion concentration to be 2.44 mg/l while Rabe et al. (1990) found calcium to be 8.0 mg/l and magnesium to be 0.5 mg/l.

Ecosystem changes taking place in communities at Hager Lake and within *Penstemon lemhiensis* habitat are occurring subtly over the course of decades. Further research and long-term monitoring studies will elucidate the processes operating to effect changes in plant populations and ultimately to the long-term management and conservation of these ecosystems.

RARE PLANT CONSERVATION ACTIVITIES

U.S. Fish and Wildlife Service. Several federal and state agencies and organizations have rare plant conservation programs, the most important being the federal Endangered Species Act, administered by the U.S. Fish and Wildlife Service (FWS). Only those species that are globally rare and threatened fall under the act in one of several classifications. Below are the classes, with the corresponding definition and number of Idaho plant taxa so classified (**Federal Register** 21 February 1990):

LISTED TAXA

Endangered (taxa in danger of extinction throughout all or a significant portion of their range) 1

Threatened (taxa likely to be classified as Endangered within the foreseeable future throughout all or a significant portion of their range) 0

CANDIDATES FOR LISTING, in three categories:

Category 1 (taxa for which the FWS currently has substantial information on hand to support the biological appropriateness of proposing to list as endangered or threatened) 19

Category 2 (taxa for which information now in possession of the FWS indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support listing) 28

Category 3 - Taxa that were once considered for listing as endangered or threatened, but are no longer receiving such consideration, in three subcategories:

3a (taxa for which the FWS has persuasive evidence of extinction) . 1

3b (taxonomic status is in question) 1

3c (taxon is more widespread or abundant than previously thought, or is not subject to identifiable threats) .... many

Idaho Department of Parks and Recreation As mentioned earlier, Idaho has a rare plant protection law that is administered by the Department of Parks and Recreation. It is largely meant to protect wildflowers from being removed along public roads. There are some strongly worded sections, however, that seem reasonable today but were quite visionary 25 years ago when they were written, for example the first three sections state (**Idaho Code** 18-3911):

"(1) It is the duty of all citizens of this state to protect the wildflowers of this state referred to in this section from needless destruction and waste."

"(2) It shall be unlawful for any person in this state to wilfully and negligently cut, dig up, trim, pick, or remove, any plant, flower, shrub, bush, fruit or other vegetation growing upon the right of way of any public highway within this state."

"(3) It shall be unlawful for any person to export from this state, or to sell or offer for sale or transport bulbs, corms, rhizomes, roots, or plants of native wild flowers or shrubs of the state of any of the following genera:"

a. Tiger lily ... *Lilium columbianum*
b. Queen Cup ... *Clintonia uniflora*
c. *Trillium* (both species)
d. Lady's Slipper ... *Cypripedium montanum*
e. Stream orchis ... *Epipactis gigantea*
f. Coral root ... *Corallorhiza* (all species)
g. Columbine ... *Aquilegia formosa*
h. Syringa or mock orange ... *Philadelphus lewisii*
i. Dogwood ... *Cornus nuttallii* and *C. canadensis*
j. Indian Pipe Family (all members)
k. Rhododendron (all species)
l. Twin Flower ... *Linnaea americana*
m. Mission bells or rive root ... *Fritillaria lanceolata*
n. Bitter root ... *Lewisia rediviva*
o. Angel slipper, fairy slipper ... *Calypso bulbosa*

Later sections deal with exemptions for highway workers, prosecution of violators, and, most importantly, authority to amend the list "in order to further protect native wild flowers from needless destruction and waste." Only three species listed in the code are currently on the Idaho rare plant list: *Epipactis gigantea, Cornus nuttallii*, and *Corallorhiza wisteriana* (Idaho Native Plant Society 1992). This law has never been enforced although it has allowed the State of Idaho to qualify for federal matching money for rare plant conservation activities under the ESA.

Idaho Native Plant Society The only non-governmental organization in Idaho specifically focused on the conservation of the state's flora is the Idaho Native Plant Society. Their stated goal is to "foster the understanding and appreciation of Idaho's native flora and to preserve this rich resource for future generations." With six local chapters around the state, they accomplish this goal largely through education, including field trips, newsletters, and presentations, as well as special events, such as the Idaho Natural Areas Conference that took place in October, 1991, and the annual Idaho Rare Plant Conference. They are also beginning to take a more activist role in rare plant preservation.

U.S. Forest Service Under the ESA the U.S. Forest Service is obligated to preserve, protect and enhance all species listed as endangered or threatened. It also has a policy for Sensitive species (Forest Service Manual 2670), defined as follows:

> "Taxa that are identified by the Regional Forester for which viability is a concern, as evidenced by significant current or predicted downward trends in population numbers or density, or significant current or predicted downward trends in habitat capability that would reduce a species existing distribution."

This is a proactive policy to protect and manage for non-listed rare plants so that they do not decline to the point where they qualify for listing under the ESA. It also instructs managers to assist states in their efforts to protect rare elements of their biota. There are 13 Forest Service administrative units in Idaho, including seven National Forests in Region 4 (southern Idaho), five National Forests in Region 1 (northern Idaho), and the Hells Canyon National Recreation Area administered by the Wallowa-Whitman NF in Region 6. Although this policy has been around for many years, only recently has public attention begun to focus on preserving biological diversity, in general, and rare plant conservation, in particular. There has been a concomitant increase in botanists on several Idaho National Forests in recent years. Although still inadequate in many areas of the state, the Forest Service is continuing to hire additional botanical staff to manage their rare plant conservation programs.

Bureau of Land Management A similar situation exists in the Bureau of Land Management (BLM). They are obligated to preserve listed species and also have a policy to manage and protect Sensitive species in a proactive way, as follows (BLM Manual 6840):

> "Sensitive species are those designated by the state director, usually in cooperation with the state agencies responsible for managing the species as sensitive. They are those species that are 1) under status review by FWS; or 2) whose numbers are declining so rapidly that federal listing may become necessary; or 3) with typically small and widely dispersed populations; or 4) those inhabiting ecological refugia or other specialized or unique habitats."

There are six BLM Districts in Idaho, mostly in the south, with nearly all having either full-time or seasonal botanists on their staff. As with the Forest Service, the hiring of botanists to administer the rare plant programs has increased in the last few years, a trend that appears to be continuing.

Idaho Department of Fish and Game The Idaho Department of Fish and Game's Conservation Data Center is part of the Network of Natural Heritage Programs and Conservation Data Centers that now include more than 100 installations in all 50 states, three Canadian provinces, and 13 Latin American countries, as well as a number of national parks, forests, and other areas (Master 1991). This worldwide information network was developed by The Nature Conservancy, and is directed toward the conservation of biological diversity. We currently have over 3000 occurrences of rare plants entered into our data base for Idaho. These data are widely used by federal, state, and municipal agencies, as well as private groups and individuals, for the proactive management and conservation of rare plants in Idaho.

FUTURE NEEDS

Below are six areas that I view as needing increased emphasis and funding in the future, so that rare plant conservation in Idaho can be accomplished in an efficient and effective manner:

1. Mosses, liverworts, lichens and fungi should receive more attention, both from floristic workers and from conservation biologists. I was glad to see that bryophytes were added to the Flora of North America project (Anonymous 1991). The lichens of southwestern Idaho were recently catalogued (McCune 1992a) and a status survey for a rare soil-crust lichen, the monotypic *Texosporium sancti-jacobi*, was recently completed by the Boise District BLM (McCune 1992b).

2. We still know very little about the distribution and abundance of many of our rare taxa, and this type of rare plant conservation work is still a priority. But we also have major information gaps for those rare species for which we have adequate distribution, abundance, and threat data. The information gaps can only be filled by monitoring and by research programs that answer questions about the long-term persistence of these taxa in the landscape. Studies dealing with reproductive biology and habitat relationships, assessing genetic diversity of species and populations, and monitoring population demography and dynamics all provide important data needed in developing long-term conservation strategies for the rarest species. Right now biologists are making life and death decisions based on very little data; we have no choice.

3. Strengthen the state rare plant law. The current law is good as far as it goes, but it needs to have: (1) improved enforcement; (2) stronger protection for rare taxa; and (3) an amended list that includes those species most in need of protection.

4. Botanists specializing in rare plants need to begin working in a ecosystem and landscape context. Many of the declining species in this state are only indicators of a much broader biological impoverishment, the consequences of which are greater than the loss of a single species.

5. The conservation of biological diversity begins with a catalogue of all its elements. Recent treatments of Idaho's flora are incomplete and the older treatments are rapidly becoming outdated. The partially-complete Intermountain Flora project of the New York Botanical Garden is an excellent and much-needed resource for those of us working in southern Idaho. New treatments such as the continent-wide Flora of North America project organized by the Missouri Botanical Garden (Morin 1986), the Flora of the Rocky Mountains project (Hartman 1992), and the Flora of East-central Idaho (Henderson 1992) are urgently needed and can not be completed too soon. Smaller-scale inventories and checklists should also be developed. These and other floristic analyses, such as the development of floristic regions for Idaho (Ertter and Moseley 1992) and continued paleobotanical studies (Packard 1992) will shed further light on the evolutionary processes operating on Idaho's flora and will have direct bearing on how conservation biologists proceed with maintaining the floristic diversity of Idaho.

6. Finally, and I feel most importantly, we must educate. As biologists we are in the best position to interpret the wealth of knowledge contained in Idaho's biological resources and the importance of that wealth to the economic and spiritual well-being of its citizens. We need educated citizens and politicians that understand the importance of preserving biotic diversity and the consequences of not doing so.

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BOOK REVIEW

Sagebrush Country — A Wildflower Sanctuary by Ronald J. Taylor. 1992. Mountain Press Publishing Company, 2016 Strand Avenue, P.O. Box 2399, Missoula, Montana 59801. ISBN 0-87842-280-3. 211pp. $12.00.

Do we need yet another book on western North American wildflowers? After examining this newly-released volume the answer is a resounding, "YES." Mountain Press refers to this as a "revised" edition of the same title. The earlier edition by Taylor and with excellent photos by Rolf Valum was among my prized wildflower books. The revised edition is even better! **Sagebrush Country** combines well-organized, highly informative text with superb photographs. The reader is treated not only to the "standard" inclusions of most wildflower books, but is also introduced to sections explaining ecologic features of the shrub steppe, including vegetation zones and some soil-plant patterns that contribute to the remarkable diversity found in sagebrush country. Those seeking accurate and succinct explanations of plant names will be pleased to find this section also. The author even includes brief but informative sections on "Pollination Strategies of Steppe Wildflowers" and "Animals of the Sagebrush Steppe" with a few photographs by a well-known Pacific Northwestern photographer, Ira Spring.

Arrangement of the photographs and descriptive text for the plants included is alphabetic by plant family. This presupposes some knowledge of family relationships; those with a modest background in wildflowers will find the organization useful. For those lacking this knowledge a dichotomous key to the plant families included in this book is available in Appendix 1. The key is worded in such a manner that even the wildflower neophyte will find it easy to use. Once the family name is discovered it is a simple task to find the family section alphabetically. A nice touch with the family key is the inclusion of variability within each family only as it is present in the Western North American shrub steppe region, thus eliminating much of the data that often renders keys cumbersome. Because many of the species included have rather broad ecologic amplitudes, the book will be useful to some extent even beyond shrub steppe habitats.

In assembling any wildflower book the author is always faced with the problem of which common plants to exclude. **Sagebrush Country** is a successful mix of the more common flowering plants with some that often are excluded from such treatments; here the reader will also find the important shrubs and grasses that are responsible for much of the character of the shrub steppe.

Each species included has a short but informative description integrated with other useful and interesting facts, often including derivation of names and notes on abundance and distribution. Where appropriate, comments about pollination are also included.

Special mention of the photographs is in order. Many wildflower books suffer because of the photographs included; although pleasing to the eye, the photographs frequently fail to render important diagnostic features with sufficient clarity to be useful in identification — or worse yet, depict the *wrong* species. Perhaps the best combination is for the author-photographer to be also a professional field botanist. Dr. Taylor combines his professional expertise in field botany (ecology and systematics) with obvious expertise with lens and film to produce stunning photographs that are not only aesthetically pleasing but also technically accurate.

Also included is an index listing scientific names of plant species according to their more common habitats, e.g., *Balsamorhiza hookeri* and *Allium robinsonii* are included within the "Lithosol Zone." An illustrated glossary with somewhat overpowering and slightly crude (but accurate) line drawings precedes a more traditional verbal glossary (also accurate). The final few pages include a Cross Reference of Scientific and Common Names and two indices, one for scientific names and one for common names.

The text is remarkably error-free; the only obvious one seen was "*Balsamroot rosea*" in the caption for "*Balsamorhiza rosea*." In a very few cases the author could have used more recently accepted scientific names for some of the included species (either *Koeleria macrantha* or *Koeleria pyramidata* for our native June grass rather than the illegitimate name, *Koeleria cristata*). These are only minor criticisms and do not detract from the overall quality.

Taylor and Mountain Press should be proud of this excellent edition. Plant lovers will find this a a valuable and enjoyable tool for botanizing in sagebrush country.

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— NOTES —

INFORMATION FOR CONTRIBUTORS

Contributions to the JOURNAL OF THE IDAHO ACADEMY OF SCIENCE may be in all fields of science or science education which relate in some manner to the state of Idaho and have not been published elsewhere.

Manuscripts submitted (in triplicate) to the Editor should be double spaced throughout with ample margins and typed on only one side of the paper. Regular articles include, in order, the following: title, author(s) name(s), author(s) address(es), abstract, key words, text (with desired headings), acknowledgments, literature cited, tables and figure legends. First mention of scientific names should include authority. Manuscripts are generally limited to 20 printed pages. In brief articles, the text is not subdivided. The abstract should be complete and understandable without reference to the text. The scope of the article should be stated in the introduction or, in the case of brief articles, an introductory paragraph. Footnote material should be incorporated in the text whenever possible. Authors should follow the suggestions in the latest edition of the CBE Style Manual (AIBS) for abbreviations, punctuation, and similar matters. All numerical measurements should be given in the metric system with the English system following parenthetically where desirable.

Tables and figures should be kept within economic limits. Tables should be typed on separate sheets. Lettering and line drawings must be of letter quality (i.e., laser printing or India ink). Figures should be planned for no reduction when printed; thus, they may be no larger than 11 x 17 cm (4-1/2 x 6-3/4 inches). If photographs are submitted, they must be hard glossy prints of good contrast. Legends must be brief; legends for several figures may be placed on a single sheet. The manuscript on a disk after final revision would also be appreciated.

Page proof will be sent to the author. Reprints can be ordered when the author returns the proofs; 50 reprints of each article will be furnished free. Illustrations will be destroyed unless their return is requested on the reprint order.

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