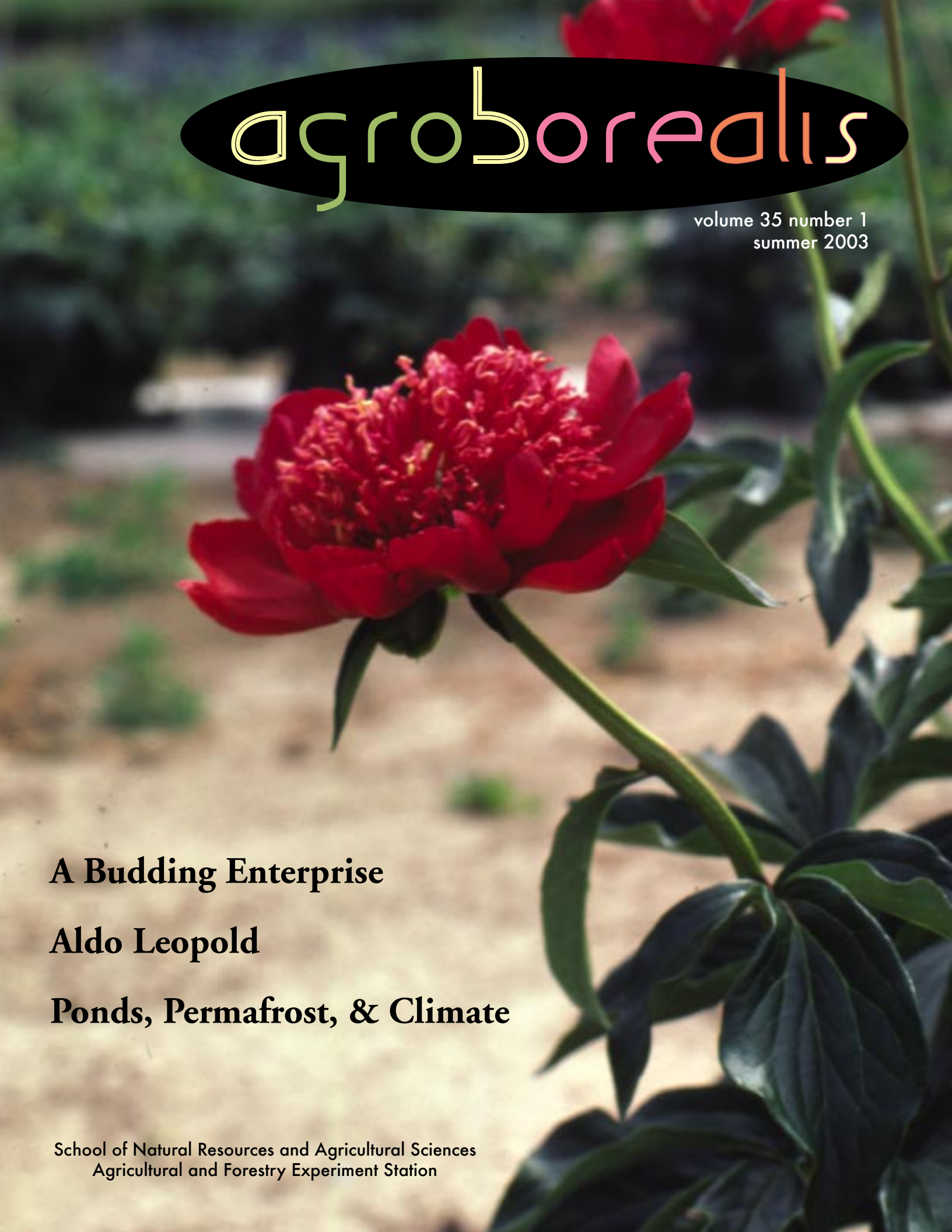


agroboreali s

volume 35 number 1
summer 2003

A Budding Enterprise

Aldo Leopold

Ponds, Permafrost, & Climate

School of Natural Resources and Agricultural Sciences
Agricultural and Forestry Experiment Station

—Georgeson Botanical Garden Collection

contents:

About the cover: *Peonies grown in the Georgeson Botanical Garden. This variety, photographed in 2000, is called Charm.*
—Photograph by Jan Hanscom

Agroborealis is published by the Agricultural and Forestry Experiment Station, University of Alaska Fairbanks. For more information about our research and education programs, please contact us at:

School of Natural Resources & Agricultural Sciences
P.O. Box 757140
Fairbanks, AK 99775-7140

Office of the Dean
(907) 474-7083
fysnras@uaf.edu

Student Information
(907) 474-5276

or visit our website:
http://www.uaf.edu/snras

Changes of address and requests for a free subscription or extra copies should be addressed to:

AFES Publications
P.O. Box 757200
Fairbanks, AK 99775-7200

fynrpub@uaf.edu

Agroborealis, Natural Resource News, and other publications are available in alternative formats. Please include your e-mail address if you would like e-mail notification of online availability of our periodicals and other publications. You may download them from our website at:

http://www.uaf.edu/snras/AFES/AFESpubs.html

Agroborealis is produced by the AFES Publications Office.

ISSN: 0002-1822

Managing Editor
Deirdre Helfferich

Information Officer/Science Writer
Doreen L. Fitzgerald

Webmaster
Steve Peterson

letter from the dean:

The mission of the School of Natural Resources and Agricultural Sciences and the Agricultural and Forestry Experiment Station is to generate and provide knowledge that is important for the successful long-term management of natural resources in Alaska and the circumpolar world, and to discover, describe, and interpret the spatial characteristics of the northern regions of the Earth. This issue of *Agroborealis* highlights the diversity of the school and the experiment station and directs your attention to what we do.

We provide information that will help all of us ensure that management of the state's natural resources leads to sustainable development of these resources. New floral crops, alternative livestock appropriate to the circumpolar north, use of electronic tools to monitor the circumpolar ecosystem, and public forums concerning wildlife interaction with the human population are but a few of our areas of interest. We look to the past to bring you information relevant to the future. Aldo Leopold embarked on a career that led him to establish the field of wildlife management nearly a century ago. Our students found that his information is relevant today. We also look to the future in the partnerships we are creating. The USDA Agricultural Research Service and the Forest Service are working with us to provide cutting edge information to not only food and fiber producers, but also to managers of public and private lands. The North and West Alaska Cooperative Studies Unit and interdisciplinary graduate studies in regional resilience and adaptation will provide research and instruction opportunities for the natural resource managers of tomorrow.

I think this is one of our more exciting issues of *Agroborealis*. We are shaping new and diverse directions for the School of Natural Resources and Agricultural Sciences and the Agricultural and Forestry Experiment Station. At the same time, we are maintaining our traditional emphasis in agriculture and forestry, but with a new look at new crops and livestock. I hope you share my enthusiasm for our work. I also welcome you to share your ideas with us about natural resource management and sustainable development.

Sincerely,
Carol E. Lewis

letter from the associate director:

As this issue of *Agroborealis* goes to press, the governor is reviewing the budget passed by the Twenty-third Alaska Legislature and has promised the largest gubernatorial veto package in the state's history. Most state agencies and the University of Alaska will undoubtedly feel the pinch in their FY04 general fund budget. The Agricultural and Forestry Experiment Station continues to address potential shortfalls and resulting program reductions with assistance from our federal legislative delegation. Selected early results of federal partnerships being pursued are outlined in this issue. These include USDA Special Grants for new crops such as peonies ("Peony—A Future Crop for Alaska?"), USDA Hatch and Special Grants for research with alternative animal species ("Alternative Livestock in Alaska: Bison to Yaks"), and new cooperative research programs with the newly established Subarctic Agricultural Research Unit in Fairbanks and Palmer. The latter marks the long-awaited reestablishment of the USDA Agricultural Research Service in Alaska. We will continue to report to our stakeholders on many more new programs and projects resulting from these and other university, state, and federal cooperative ventures in natural resources and agricultural sciences.

G. Allen Mitchell

Peony—A Future Crop for Alaska?

Doreen Fitzgerald

Above: Paeonia lactiflora, *Chinese Peony.*
—PHOTOGRAPH © 1999 DR. NICK V. KURZENKO

Below: pink single blossoms of the domestic peony, a variety called Sea Shell.
—2001, GEORGESON BOTANICAL GARDEN COLLECTION

Whether commercial growers in Alaska might someday export peonies for the cut flower market is the subject of a ten-year research project at the Agricultural and Forestry and Experiment Station (AFES). The peony is a long-lived, low-maintenance, and cold-tolerant plant that produces a high-value crop. Exporting flowers from as far north as Fairbanks may seem unlikely, but the late bloom period of high-latitude peonies actually provides a commercial advantage: they would be marketed when they're unavailable from other North American producers. A commercial crop from Alaska could extend the peony season for national cut flower markets.

The peony plant produces a succession of blooms over about eight weeks. At lower latitudes, they bloom mostly in May and June. At Dutch flower auctions, according to the *International Cut Flower Manual,* 52 percent of all peony cut flower stem sales occur in May, 44 percent in June. Peonies are also grown commercially in Chile, where they are ready for market in January and February. In Alaska, due to the late spring, peonies bloom from mid to late summer (July and August).

"For someone motivated to develop and commercially produce them, peonies are an interesting alternative crop," said economist Hans Geier, research associate at the School of Natural Resources and Agricultural Sciences and AFES. "Along with the seasonal advantage, we have adequate air freight service to both Europe and the Orient, as well as the contiguous United States." Because peonies are a perishable, high-value crop, they are usually shipped air freight to the wholesale buyer, who pays the freight charges.

Peonies belong to the family *Paeoniaceae* and the genus *Paeonia*, within which there are a number of species and many cultivars. Both herbaceous and tree peonies are perennials, but tree peonies, which grow to eye level on woody stems with few branches, are not used for cut flowers. The more commonly grown herbaceous peony is a bushy plant, with green, pink, or red stems that grow two to four feet tall and turn green by the time they are cut down in the fall. Each cultivar has leaves a particular shade of green, with shapes ranging from broad to grass-like. Flower colors are white, yellow, cream, pink, rose, and deep red. Peonies are grouped into types according to the petal shape: single, Japanese, anemone, semidouble, bomb, and double. After winter, the plant emerges as dark red shoot that in just a few weeks will become a lush, two- to four-foot bush. The large blooms last only a week or so, but in the home garden, selecting early, mid-season, and late cultivars can provide up to eight weeks of bloom.

"Our AFES research project aims to identify which peony cultivars are suitable for commercial cut flower production in Alaska and what potential pest and disease problems exist that might influence management of commercial fields," said Pat Holloway, associate professor and director of the Georgeson Botanical Garden. Conducting the study with her are horticultural assistant Janice Hanscom, and Grant Matheke, superintendent of the botanical garden. "Because no large-scale commercial production exists here, little is known about peony cultivation as a field-grown cut flower in Alaska," Holloway said. "In home gardens, given ample snow cover and a warm, sunny location, they are known to bloom reliably for many years."

The report of the first year's research will be published this year by AFES as a research progress report. Because peonies are not commercially harvested until at least the fourth year after planting, the AFES research data for the first year is preliminary. The research is funded by a special grant sponsored by U.S. Senator Ted Stevens through the U.S. Department of Agriculture (USDA) Cooperative States Research, Education, and Extension Service.

The Peony Market

According to the Kansas Cooperative Extension Service, there is a revived market for peonies, which in the United states traditionally were sold for Memorial Day grave decoration. Today they're used in flower arrangements, wedding bouquets, and special large arrangements for such clients as hotels. Most wholesalers want large quantities, and have an apparent preference for white peonies over red or pink. Whatever market is chosen, peonies are sold in the bud stage with instructions to the buyer on how to open the flowers for the longest vase life. The USDA has established standards for grading commercial peonies.

Before investing in roots, plants, or equipment, a potential grower should understand the cut flower market and identify market strategies. A profitable and sustainable business requires the producer to be flexible, identify more than one outlet. Outlets for commercially grown flowers are:

- Direct retail markets: farmers markets, roadside markets, restaurants, caterers;
- Local wholesale markets: florists, grocery stores, flower brokers, freeze-drying operations;
- Regional, national, and international wholesale markets: cooperatives, flower brokers, craft supply markets.

For the peony grower, there are several important concerns:

- suitability of varieties for commercial cutting and handling;
- recognition of the proper stage of maturity for cutting (varies widely among varieties);
- the speed with which flowers can be cut, graded, and stored;
- proper storage conditions before shipping;
- proper crating, packing, and identification of grade.

The best plants for commercial production bloom freely and reliably from year to year and produce a single bud or a stem with few laterals, because this requires less labor for disbudding. The qualities of a highly marketable peony include: good color and attractive form through all stages of development, preferably with a double flower; desirable fragrance; stiff, wiry, straight stems of uniform length (20–32 inches); low-set foliage of good color and quality; tolerance for abuse during shipping; and responsive to storage and water treatments.

First Year Trials in Fairbanks

One hundred fifty peonies purchased during fall of 2000 were potted into ProMix horticultural peat-lite mix, and stored at 40° C until April 2001, when the pots were moved to a greenhouse with a minimum night temperature of 100° C. On June 1 they were moved to a cold frame for hardening and further growth. The containerized peonies were planted between August 15–20 into a south-facing plot at the Georgeson Botanical Garden on the AFES farm in Fairbanks.

The peonies were planted in Tanana silt loam soil in double-row raised beds covered with landscape fabric for weed control. Each row was equipped with a double row of Ro-drip trickle irrigation. On a raised bed one meter wide, plants were spaced 46 centimeters (about 18 inches) apart within the row with approximately 18 inches between rows. Holloway said that the second phase of her project will investigate the effects of this spacing, which is tight compared to garden standards.

The experimental design consisted of six plants for each of thirty cultivars, some of which are shown in the list on page 6. To account for the growth advantage at the outside edge of the plot, guard rows of Sarah Bernhardt peonies were planted at the ends of each row and along the length of each row on the east and west edges. Plots were mulched with spruce branches in October, 2001. Because stems were not harvested, no data were analyzed statistically during year one.

Most peonies survived the winter despite a lack of early season snow. The cultivars varied widely in vegetative growth, ranging from less than one vegetative stem per plant to more than twelve stems. Plant height is related to latitude and duration of winter chilling temperatures. For instance, average stem length in Fremont, California, is 25 cm; in Pantego, North Carolina, 45 cm; and in the upper Midwest states, 60–90cm, according to Stimart. The first-year stem length in the trials averaged 46 + 12 cm and ranged from 0.3 cm to 63 cm.

All cultivars except Jaycee, Mrs. FDR, and Shawnee Chief bloomed. All were listed in commercial sources as early or midseason bloomers at lower latitudes, with May and June bloom times given by Stimart (1985) and Gast (2000). In their first year grown in Alaska, the bloom season began June 30 and extended through August 7. Some differences in bloom times were recorded for the Alaska-grown plants, but factors such as number of blooms per plant and number of plants with blooms influence the length of bloom season.

"This first-year project has shown that a variety of cultivars may be grown in Alaska and that it may be possible to select plants for various seasonal bloom times," said Holloway. "Selecting additional cultivars for late-season cultivars may extend the harvest season into late August."

Floral stem lengths were well within the range of cut flower production from lower latitudes, but as Holloway pointed out, one season is too early to predict flower quantity and quality in each cultivar. "During our first season, no disease or insect pests were recorded on any of the cultivars," she said.

The most common diseases of peonies are gray mold *(Botrytis cinerea)*, Peony leaf blotch *(Cladosporium paeoniae)*, Phytophthora blight *(Phytophthora cactorum)*, root rots (*Fusarium* sp., *Rhizoctonia solani, Sclerotinia sclerotiorum,* or *Thielaviopsis basicola*) and root-knot nematode (*Meloidogyne* sp.). Gray mold can be so severe as to jeopardize cut flower production for many years, according to Stevens (1993) and Stimart (1985).

Peony Cultivars in Year One

Better Times
Bowl of Beauty
David Harum
Doris Cooper
Duchess de Nemours
Felix Crouse
Felix Supreme
Festiva Maxima
Florence Bond
Gardenia
Gay Paree
Jaycee
Kansas
Karl Rosenfield
Louis Van Houtte
Mighty Mo
Mons. Jules Elie
Mrs. FDR
Nancy Nicholls
Pink Parfait
Princess Bride
Sara Bernhardt
Shawnee Chief
Therese
Vivid Rose

Economics

Establishing a commercial peony growing operation is no small investment in either time or money. The grower must wait five years for full production, and initial costs could be has high as $350,000, including fixed and operating expenses for five years. However, it appears that a successful one-acre operation could be very profitable.

Flowers are not harvested for at least the first three years after planting. During this time, the buds are merely pinched off, leaving as many leaves as possible on the plant to increase plant size. According to the Kansas Cooperative Extension Service, each plant can be expected to produce 20–30 flower stems in the fourth year. Only one-third of these should be harvested. The remaining flower buds should be pinched off to maximize leaf surface area and plant development. From the fifth year on, a mature, vigorous plant should produce 36–50 flower stems, half of which should be left unharvested to maintain the health and productivity of the plant.

As a senior thesis, 2002 graduate Marie Klingman investigated the production and transportation considerations for exporting peonies from Fairbanks, Alaska. She cites the *International Cut Flower Manual* in her analysis of plant yield at ten blooms per plant. She reported that a spokesman for Mayesh Wholesale and Retail in California said that in 1999, for example, peony prices ranged from 75 cents to $4.00 a stem.

Because an acre of peonies can sustain 10,000 plants, at a modest 10 stems per plant the plot would produce 100,000 stems a year. If a moderate wholesale price of $1.50 per stem was obtained, the acre of peonies would gross $150,000; 20 stems per plant would gross $300,000 a year.

According to Klingman's analysis, the startup cost for a one-acre, drip-irrigated peony bed in Fairbanks (2001) would be about $173,060, of which $138,000 is the cost of a vacuum cooler for post-harvest refrigeration. This cost could be reduced if another means of refrigeration was obtained. The 10,000 peony crowns for a tightly spaced acre would cost from $19,000 to $37,000, depending on the variety. Klingman also included a small service building ($12,000) constructed in the second year, and a truck purchased in year three. The refrigeration would not have to be in place until the fourth year, before the first harvest.

Operating costs in the second and third years would be low ($3,353) because there is no harvest or packing expense. In year four, the first harvest year, operating costs would rise to about $32,000, largely due to labor and the cost of packing and shipping materials.

Klingman's analysis shows that during the first five years (two of which are harvest years), the total gross income could

vary from $112,500 to $600,000. Five-year total expenses would range from $331,000 to $348,000. If 10 stems per plant were sold at a moderate price, the first five years of operation could cover the startup and fixed expenses.

Peony plants have a productive life of up to twenty-five years. In years five to twenty-five, the gross income could range from $75,000 to $400,000 a year. Expenses for full production would be about $55,000 annually, most of which is the cost of labor, which was estimated at $12 an hour.

Growing Peonies

Soil

Herbaceous peonies do well in a wide range of climates and soil types, but prefer a fertile, clay loam, with well-drained subsoil, which helps prevent root rot and fungal disease. The optimum soil pH is 6.5. The plants grow from an underground crown and have either pointed or large, bulky roots. After the blooming season, stem buds called eyes form at the stem base, and these buds are the source of new stems in the spring. Flowers are terminal, with one to three lateral buds. Before planting, as much organic matter as possible should be added to the soil. This is done well in advance of planting to allow the soil to settle and prevent the plants from sinking. The soil is plowed to a depth of one to three feet and allowed to settle. Deeper plowing facilitates root growth, with a corresponding increase in the plant size and amount of bloom.

Planting

Plant peonies in full sunlight, away from the competitive effects of tree roots. Choosing a sheltered location will protect the plants from wind damage. The location should be permanent, because after transplanting, peonies should not be harvested for the next three years.

Peonies, which go dormant in late August, can be planted between September 1 and freeze up. Allow enough time before frost for the soil to settle in around the roots. Stock dug the previous fall and kept in cold storage over winter can be planted in the spring, but such peonies will be less vigorous the first year because the root system will have had a shorter time to develop.

Plant spacing depends on cultivation method. For cross cultivation, space four feet every direction. Peonies are more commonly planted in rows, with a 24- to 36-inch spacing between plants and four feet between rows. The AFES study will look at the effects of tighter spacing. Dig each hole large enough to accommodate the root without crowding it. In heavy clay soil, plant so the buds are one to two inches below the soil surface. If the soil is light and friable, two to three inches is the proper depth. If the roots are planted too deep, a gnarly and much-branched stem develops between the roots and the shoots. These plants are predisposed to decay or develop galled overgrowth. Too-shallow planting allows root displacement by frost during winter or early spring, and roots too near the surface may become exposed, increasing the chance of rot or injury from cultivation. Small divisions need extra care and should be planted no deeper than two inches.

Care should be taken not to plant the root upside down. Because air pockets in the soil will dry out and kill roots, fill soil in around the roots until no voids are left below the plant or among the rows. Firm the soil well and fill in until it just covers the roots and buds. Pour in about a gallon of water and let it settle, then fill in with loose soil, mounding it a few inches for winter protection and to keep the roots from heaving. Normally, the mound will sink to proper level. If it does not, level it in the spring. As the peony grows older, the crown naturally pushes upward and has to be covered with soil.

Mulching

After the ground freezes, mulch plants with leaves, wheat straw, or other material to prevent them from being heaved out of the ground through alternate freezing and thawing. An Alaska grower probably should mulch every winter as insurance against a lack of snow cover. In general, mulching after the first winter is usually not necessary, except in the case of tiny divisions or young seedlings, which should be mulched for several years. Do not use manure or dead peony leaves and stems as a mulch. The mulch is removed as soon as the shoots break through the ground in spring. Young peony plants are particularly slow in shoot appearance and may be a month later than established plants. When the soil is sufficiently dry, shallow cultivate to break up the soil crust, being careful not to injure roots near the soil surface.

Disbudding

Disbudding is the removal of lateral flower buds growing in the leaf axis so that all of the plant's resources contribute to one flower per stem, which enhances growth of the terminal flower bud. It is done when the auxillary buds are barely

A hardy early bloomer, possibly a hybrid, donated to the garden by Jana Gordon.
—PHOTOGRAPH COURTESY GEORGESON BOTANICAL GARDEN COLLECTION

large enough to handle. For specific markets and with certain cultivars, the terminal bud is removed to promote lateral bud development or spray types. If quantity is desired and smaller flowers with little stem length are acceptable, lateral buds may be allowed to develop. Because peonies grown for cut flower markets are cut when in bud, the plants may not require staking in normal weather conditions.

Water

Peonies need a liberal supply of water, especially while blooming. Although they can withstand dryness to the point of drought, a reasonable amount of moisture is essential for the best development. Attempting commercial production without supplemental irrigation would be unwise, due to the crop's value and market demands. Drip irrigation is recommended, because overhead watering could physically damage the flowers, cause spotting on the petals, splash soil onto the foliage and promote the spread of disease. The amount and frequency of water required will vary with the weather and crop maturity. The irrigation schedule is based on soil moisture in the root zone. Care should be taken to avoid over watering, which promotes root rot.

Fertilizers

Before a fertilizer program is initiated, the soil always should be tested for nutrient content. The increased water requirement of cut flowers increases fertilization requirements. Fertilizer is applied as needed. One to two pounds of actual nitrogen per 1,000 square feet of production area per year of a 1-1-1 ratio fertilizer is adequate for plant growth and flower production. One half of the annual amount of fertilizer is applied at the time of shoot emergence in the spring. The second half can be applied after the plants go dormant in the fall. Keep all fertilizers away from the crowns and spread it over the area where the roots grow, 6–18 inches from the crown. The fertilizer is worked thoroughly into the soil around the plants. Avoid applying too much nitrogen.

Charm peony at the Georgeson Botanical Garden, July 24, 2002.
—Georgeson Botanical Garden Collection

Peony blossoms.
—Georgeson Botanical Garden Collection

Weeding

Growers must control weeds in field production of peonies, because competition with weeds reduces flower quantity and quality. A bed full of weeds also increases the time required to harvest, raising labor costs. Several options are available to combat weed growth: herbicides, barriers or mulches, hoeing, and hand-weeding.

Dried & Preserved Flowers

While not a subject of current AFES research, peony buds and blossoms may be dried by the home gardener or for the commercial market, which includes craft outlets and florists. When dried, both bud and blossom retain good color and shape. The double types are used for Victorian style winter bouquets, the single and semidouble types for contemporary arrangements. For immediate drying, flowers are harvested at the desired stage of development, or buds can be harvested and opened the desired stage before drying.

Left: Paeonia californica, *California Peony, a wild species*
—PHOTOGRAPH © 2003 BY CHARLES E. JONES

Right: wild Mountain Peony, Paeonia brownii, *growing in California*
—PHOTOGRAPH © 2001 BY JEFF ABBAS

Below: Peonies at the Georgeson Botanical Garden, summer 2002. Martha Bullock is the light variety at lower left, Kansas the darker blooms at upper right.
—GEORGESON BOTANICAL GARDEN COLLECTION

Both buds and blooms can be dried by hanging upside down or by the surround and cover method. Freeze drying also works well, but requires expensive equipment. If drying for commercial use, bunching and grading can be done in the field when flowers are to be dried immediately. Strip foliage from the bottom one-third of the stem and bunch the flower heads together. Cut the stems to the longest uniform length and secure with two rubber bands, one near the cut end and one farther up the stems. Hang the bunches to dry in a dark room at 50°F or higher with 50–60 percent relative humidity.

Single, Japanese, and semidouble flowers should be dried using the surround and cover method because it best preserves the flower shape. If using this method for double peonies, they should be only partly open. First, remove most of the stem, because the flowers dry most efficiently in shallow containers.

Choose a drying substance such as white cornmeal, sand, borax, kitty litter, silica gel, or a specially formulated product. Avoid anything that will soil the flower or be difficult to remove. Place the flowers with stems removed on a ½- to ¾-inch layer of drying substance in a container two to three inches deep. Carefully pour the drying substance over, around, and through the petals to cover the flowers. Instructions regarding light, temperature, and timing vary with the drying material. Books such as the one listed in Further Reading at the end of this article describe specific handling methods for each material.

History

In Alaska, peonies have been a favored garden flower for more than fifty years, but worldwide their cultivation history is much longer. There is evidence of their extensive use in both the Far East and Europe as long ago as two thousand years. According to Luoyang Flowers and Trees Company of Luoyang, China, the herbaceous peony, called the "queen of flowers" in China, has been cultivated there for 2500 years. The Chinese have cultivated tree peony, or "king of flowers," for more than 1500 years, and the plant is the Chinese national flower (*see* http:// www.peonyworld.com/sinopeony.htm).

—ILLUSTRATION BY JEAN HENRI JAUME SAINT-HILAIRE,

In both Europe and the Far East, peonies have been used as food and medicine, for garden beauty, and as sources of artistic inspiration. The first use of peonies by humans may have been medicinal, and many parts of the plant are used. In texts describing traditional Chinese medicine, three peony preparations are common. Mu Dan Pi, made from tree peony bark, is said to cool the blood and have antibacterial properties. Chi Shao Yao, made from herbaceous peony root, is thought to cool the blood and relieve pain. Bai Shao Yao, made from the same root, but with bark removed, is used to nourish the blood. The medicinal use of peonies in the west has been uncommon since medieval times, when two peonies were widely used: *P. officinalis* and *P. mascula* (respectively known as the female and male peony). Peonies apparently were used for childbirth, warding off evil spirits, curing jaundice and gall stones, controlling epileptic seizures, and soothing teething pain. Peony seeds have been swallowed whole to prevent bad dreams or used in a poultice to relieve stomach aches; flower petals have been dried and used to make a tea for soothing a cough. Modern research involves evaluating the medical potential of the chemical compounds in peonies. In Asia, the peonies grown for medicinal use come from China, Korea, and Taiwan. Most of the peonies harvested are grown for that purpose, though some peonies are still taken from the wild. Research there is underway to improve yields and increase the concentration of desired compounds.

Peony Societies

In 1903, the American Peony Society was organized to "increase the general interest in the cultivation and use of the peony, to improve the methods of its cultivation, to increase its use as a decorative flower, to properly supervise the nomenclature of the different varieties and kinds of peonies, to encourage the introduction of improved seedlings and crosses, and to hold exhibitions with all members participating in the showing of their homegrown peonies." This and several other societies have web sites, all of which provide more information and some of which have photographs of many peony cultivars.

The American Peony Society
250 Interlachen Road
Hopkins, MN 55343, USA
www.americanpeonysociety.org

The Canadian Peony Society
c/o Royal Botanical Gardens
P.O. Box 399
Hamilton, ON
L8N 3H8, Canada
www.peony.ca
e-mail: admin@peony.ca

The Peony Society
(formerly the British Peony Society)
www.paeonia.org
Secretary Hugh Bennison
rhbennison@waitrose.com

Heartland Peony Society
Membership c/o Jim Crist
15738 Horton Lane, Overland Park
KS, 66223, USA
www.peonies.org
(photos of 256 peony cultivars)

References

Gast, K.L.B. 2000. 1997. Production and post harvest evaluation of fresh-cut peonies. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Available on line at: www.oznet.ksu.edu/library/hort2/Samplers/srp818.htm.

Klingman, M.A. 2002. Production and Transportation Considerations in the Export of Peonies from Fairbanks Alaska. Senior thesis presented to the faculty of the School of Agriculture and Land Resources Management, University of Alaska Fairbanks and senior thesis committee: Greenberg, J. A., Geier, H. T., Holloway, P. S., and Lewis, C.E.

Pertwee, J. 2000. International cut flower manual. Elsevier International Business Information. Doetinchem, The Netherlands.

Stevens, S., A.B. Stevens, K.L.B. Gast, J.A. O'Mara, N.A. Tisserat and R. Bauernfiend. 1993. Commercial Specialty Cut Flower Production. Peonies. Kansas State University. Cooperative Extension Service, Manhattan, Kansas. Pub. MF-1083.

Stimart, D.P. 1985. Strategies of growing fresh cut flowers of Asdtilbe, Liatris and Paeonia. in: Commercial field production of cut and dried flowers. Center for Alternative Crops and Products. University of Minnesota and the American Society for Horticultural Science. pp. 121–131.

Further Reading

Catley, J. 2000. Chilling requirements of paeonia cultivars. *Hort-Research.*

Hill, K. 1998. The Peony Industry in the USA.

Gast, K.L.B. 1995. Initial vase life studies and short term storage studies. Kansas State University.

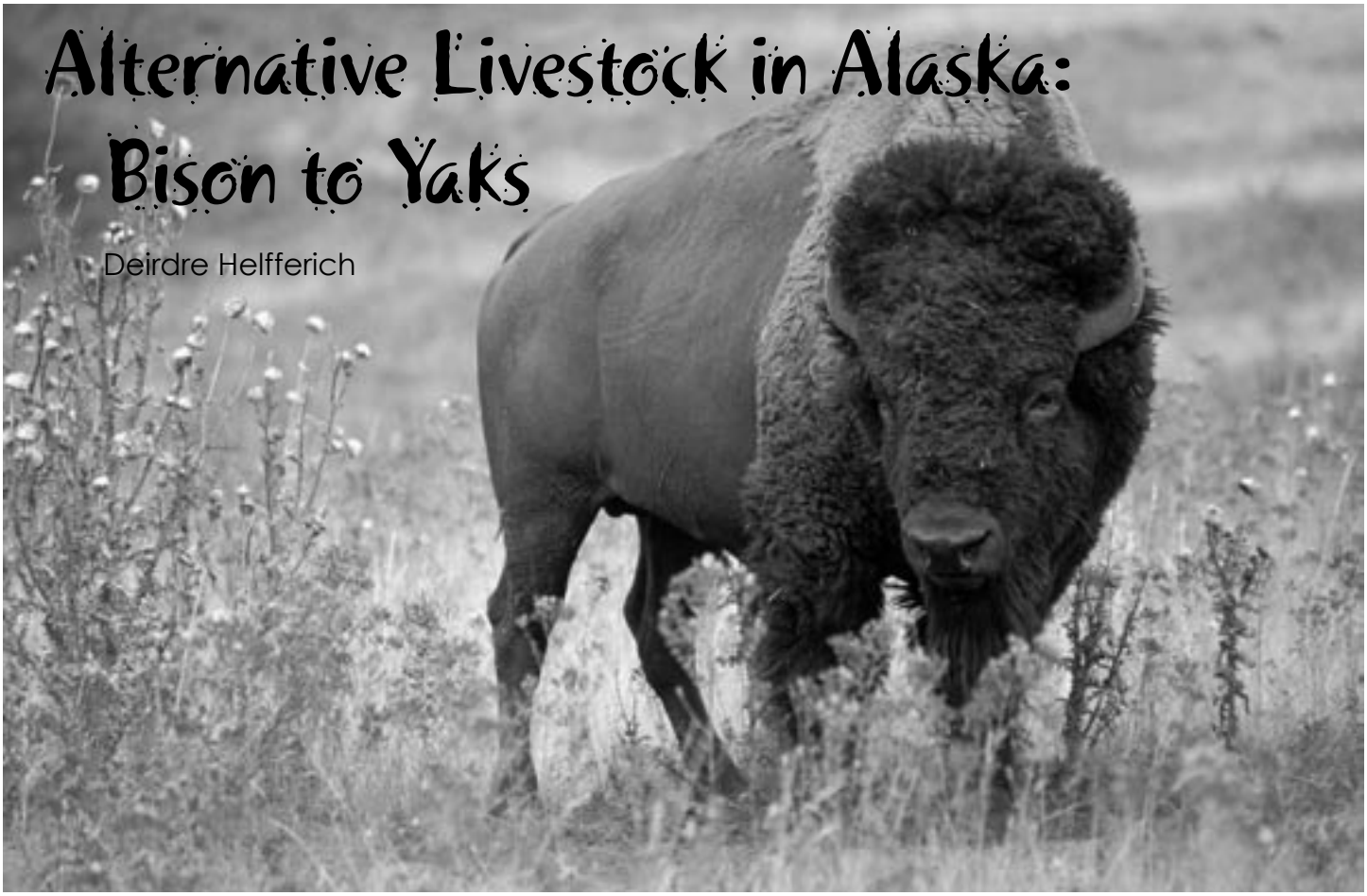
USDA. 1938. United States Standards for Grades of Cut Peonies in the Bud. Agricultural Marketing Service.

USDA. 1993. Wholesale Ornamental Crops Report. Agricultural Marketing Service.

Whitlock, Sarah, and Martha Rankin. *Dried Flowers, How to Prepare Them.* Dept. 23, Dover Publications, Inc., 31 East 2nd Street, Mineola, NY 11501.

Alternative Livestock in Alaska: Bison to Yaks

Deirdre Helfferich



—photograph by Jack Dykinga, courtesy of the USDA Aricultural Research Service Photo Unit, www.ars.usda.gov/is/graphics/photos/

Farmers in Alaska are working with an exciting range of livestock, from small creatures like the red worms at Can-O-Worms Alaska to large mammals such as elk at the Northern Lights Elk and Bison Ranch. Farmers in the field of alternative animal husbandry are raising an amazing variety of livestock: alpacas, bison, elk, llamas, musk oxen, reindeer, worms, wild swine, and yaks.

Raised for their meat, wool, antlers, or for their versatility as pack animals, large ruminants are the subject of much interest and business enterprise in the state. Scientists and agriculturalists met in Anchorage April 10–12 for an educational conference on nontraditional ruminant livestock species. Sessions covered animal management, veterinary medicine, Alaska livestock operations, and agrotourism opportunities for diversified livestock ranches and farms. Greg Finstad, Peter Fix, Norman Harris, Janice Rowell, Milan Shipka, and Mingchu Zhang of the SNRAS were among the presenters. About fifty people attended the conference, where they learned about facility requirements, nutritional and reproductive management, disease control, and the tourism opportunities associated with producing nontraditional species. Speakers at the conference were from Alaska, Yukon Territory, North Dakota, and Colorado. The first day of the conference concluded with a banquet where the main course included Alaska-produced bison, elk, reindeer, and yak. The last day involved a field trip to Northern Lights Elk and Bison Ranch, owned by Delbert and Jackie Simineo; Pitchfork Bison Ranch, owned by Todd and Roxanne Pettit; and Windy Valley Muskox Farm, owned by John and Dianne Nash.

Because bison, elk, and muskoxen are not domesticated animals, raising them is trickier than nontraditional domesticated livestock. Reindeer are considered semidomesticated or captive, and do show some differences in stature and temperament than caribou, their wild counterpart. Yaks, muskoxen, llamas, and alpacas are raised for their fiber. Some animals, like yaks and muskoxen, are adapted to cold weather and are unsuitable for warm climates. Alpacas and llamas (high-altitude camelids of South America) and Tibetan yaks are raised not only for their fiber but also are trained as pack animals. Yaks are traditionally used as dairy and meat animals as well. Muskoxen or reindeer meat entrees can be purchased in restaurants around the state, and reindeer sausage or powdered antler supplements can be found in grocery stores. Bison meat (sometimes sold as buffalo) is also available on occasion.

Agrotourism and raising alternative livestock are complementary: people are often fascinated by exotic or rare animals, and will go out of their way to see or hunt them. The Fairbanks Experiment Farm and the Large Animal Research Station at the University of Alaska Fairbanks, for example, draw many visitors each year who come to see the caribou, reindeer, and muskoxen. The privately-owned Kodiak Game Ranch offers bison hunts, and the Big Game Alaska Wildlife Center rehabilitates wildlife and offers educational programs for the public.

Aldo Leopold at the Shack, a recycled chicken coop at his farm retreat in Wisconsin.
—PHOTOGRAPH COURTESY OF THE ALDO LEOPOLD FOUNDATION ARCHIVES

The Legacy of Aldo Leopold

Literature of Science students explore naturalist's ideas

Doreen Fitzgerald

Nearly a century ago, new forestry degree in hand, Aldo Leopold embarked on a career that led him to establish the field of wildlife management. Of even greater significance, he brought to his profession a talent for writing and a natural inclination to closely observe the natural world. The notes and journals Leopold kept during his career became the basis for the sketches and essays that have been published since his death. Through these works, Leopold is known today as a scientist, naturalist, and philosopher—one who inspires, sparks debate, and has, for at least one semester, become a focal point for a small but diverse group of UAF graduate students.

"The Legacy of Aldo Leopold" is this year's theme for the course Literature of Science and the Environment, (Natural Resource Management/ Northern Studies 632). The seminar, an in-depth exploration of Leopold's ideas and influence, is taught by professor Susan Todd of the natural resources department and English instructor and writer Carolyn Kremers. The students in the course have varied academic interests and backgrounds. They include a wildlife biologist and natural resource manager, a student working on an interdisciplinary Ph.D. in literary criticism, an undergraduate natural resource management major, a graduate student working on a master's degree in global environmental politics, a master's student in northern studies, a nondegree "life-long learner," and a student in the Integrative Graduate Education and Research Traineeship (IGERT) Program who is working on a master's degree in natural resources management.

"I enjoyed three things about 'The Legacy of Aldo Leopold' course," said Jimmy Fox, refuge operations specialist for the Yukon Flats National Wildlife Refuge. "First, learning about Aldo Leopold, the person (he was human!); second, becoming cognizant of his professional life, replete with trials and tribulations; and third, watching, over a four-month period, an eclectic group of people discuss Leopold's life and work, and natural resource issues today. For me, the highlight of the course was the readings, and although I found the reading pace maddening, the selections were fantastic. There is no doubt this class has deeply enriched my personal and professional life."

"One of the things Leopold wanted most was for students from all disciplines to have a basic understanding of the principles of ecology, and I can't imagine a better forum to do it in," said IGERT student Alina Cushing. "He definitely believed that a basic ecological education in the common population was paramount to achieving sustainable use of the nation's resources. But what he also advocated that was new was a moral sense of obligation to the land, in order that one be motivated to take care of it."

During the course students read, discussed, and responded in writing to the readings cited at the end of this article. Their work included critical and

Dr. Susan Todd at the seminar.
—CLASSROOM PHOTOGRAPHS BY SHAWN SWANSON

Student Marion Avrilyn Jones reading from, above, and in mid-discussion of Leopold's work, right.

creative writing, as well as preparing and presenting a research paper. Course topics were: the making of a conservationist; significance of and critical response to Leopold's work; game management and the game manager; the wilderness advocate; and a comparison of Leopold's relationship with the natural world with the land ethics of indigenous peoples. (See page X for two samples of their written responses.)

"What I like and find most interesting about Leopold so far is the land ethic, which also came up, although not in the same context, in one of my other courses with respect to traditional ecological knowledge," said Cushing. "In that class we read a paper that suggested that the difference between traditional ecological knowledge and western traditional science is that the latter doesn't entail any moral or ethical responsibility

Dr. Carolyn Kremer engaged in discussion.

to the land or natural resources. Western science is supposed to be value-free, that is the ideal, whereas indigenous knowledge systems operate with the express purpose of teaching ethical ways of treating the land with respect so that it will always be there. Leopold's land ethic was an attempt (one of the first, as far as I know, at least by a western scientist) to meld scientific knowledge and ethics.

"What I wonder, though, and we talked a bit about this in last week's Leopold class, is how do you bring about a shift in ethics? How do we get the general public of the U.S. to feel any moral obligation to the Earth? Can we do it like the indigenous peoples do, with ceremonies, stories, and oral traditions? Maybe we can't because our culture is not at all based on that kind of tradition the way indigenous cultures are. So we need to invent our own way to do it, I guess. But I'm not at all sure how to do that. We tend to think in terms of passing legislation in order to protect the environment, but there needs to be a desire on the part of the people. I think a desire is slowly emerging and getting a louder voice, so maybe we are on the right track. But are we moving fast enough? I guess that's the imperative question."

Leopold's thoughts on ecology and the modern world were developed in the first half of the last century—well before the level of environmental consciousness and concern found today. The experiences that contributed to his ideas were gained during more than twenty-five years as a professional forester, educator, and observer.

"Leopold was not opposed to resource use, but he wanted us to exercise restraint in what we use and to appreciate the complexity of the biotic community," said Todd.

"The outstanding scientific discovery of the twentieth century is not television, or radio, but rather the complexity of the land organism," wrote Leopold in his essay, "Conservation." "Only those who know the most about it can appreciate how little we know about it. The last word in ignorance is the man who says of an animal or plant: 'what good is it?' If the land mechanism as a whole is good, then every part is good, whether we understand it or not." The essay is in *Round River: From the Journals of Aldo Leopold.*

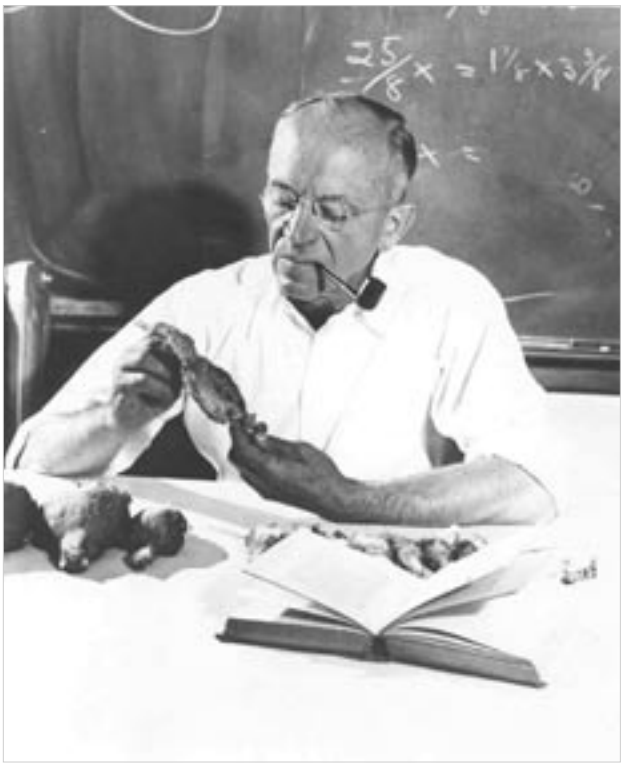
The eldest child of Carl and Clara Leopold, Aldo was born in Burlington, Iowa, in January 1887. He was educated first in Burlington public schools and later at Lawrenceville Academy in New Jersey, where he prepared for college. At eighteen he entered the Sheffield Scientific School at Yale, and the next year began course work at the Yale School of Forestry, which was founded in 1900 by Gifford Pinchot and Henry S. Graves. Both Yale graduates, they had studied forestry in Europe because at the time there were no professional forestry schools in the United States. Leopold earned his master's degree in forestry in 1909.

In his formative years, Leopold had access to higher education, educated society, training in critical thinking, and enough leisure to pursue philosophical ideas. Through his family he was introduced to many disciplines of thought: landscape architecture, drawing, horticulture and botany, animal behavior, philosophy, literature, and music.

"Because Leopold's background was so varied, he did not see things

through a single lens," said Marybeth Lorbiecki, author of *Aldo Leopold: A Fierce Green Fire,* in an interview published on the Internet. "He reacted to what he saw around him on many levels, and he fought, through his entire professional life, to break down the artificial walls between the various fields of science (ecology, botany, zoology), as well as between the sciences and literature, philosophy, ethics."

As a new graduate, Leopold joined the U.S. Forest Service, which had been established just four years earlier. His first field assignment was forestry assistant at the Apache National Forest in southeastern Arizona. Two years later he transferred to Carson National Forest in northern New Mexico as deputy supervisor. There he became a supervisor and founded and edited a newsletter, the *Carson Pine Cone.* In 1912 he married Estella Bergere of Santa Fe. Together they had five children: Starker, Luna, Nina, Carl, and Estella, each of whom achieved a distinguished career in the natural sciences.



Aldo Leopold inspects a bird specimen in his laboratory, 1938.
—PHOTOGRAPH BY ROBERT OCKING, COURTESY ALDO LEOPOLD FOUNDATION ARCHIVES

Leopold was assigned to the office of grazing at the Forest Service district headquarters in Albuquerque, New Mexico, in 1914. The next year he was placed in charge of new work on recreation, game, fish, and publicity. During World War I he left the agency for a time, but rejoined in 1919 as assistant district forester in charge of operations for the twenty million acres of national forests in the Southwest. Three years later he submitted a formal proposal for the administration of part of the Gila National Forest as a wilderness area, the first in the world, which it became in 1924. While in the Southwest, he completed a mimeographed "Watershed Handbook" for the district, which reflected observations he had made on numerous inspection tours of southwestern forests.

Leopold transferred in 1924 to the U.S. Forest Products Laboratory in Madison, Wisconsin, as assistant director. After four years, he left the laboratory and the Forest Service to conduct game surveys of midwestern states, funded by the Sporting Arms and Ammunition Manufacturers' Institute. He prepared survey reports for nine states and in 1931 published a book-length summary. As chairman of the Game Policy Institute of the American Game Conference in 1930, he led in formulating the group's American Game Policy.

In 1933, Leopold accepted an appointment to the new chair of game management in the Department of Agriculture Economics at the University of Wisconsin, and he published Game Management, the first textbook in the field and a classic that remains in publication today. That fall he studied forestry and wildlife management in Germany on a Carl Schurz fellowship, and during the next few years, he helped found the Wildlife Society. I939 he was appointed chairman of a new Department of Wildlife Management at the University of Wisconsin.

A leader of the conservation movement throughout his life, Leopold is widely acknowledged as the father of wildlife conservation in America. Although most widely known for *A Sand County Almanac,* he was also an internationally respected scientist who wrote over 350 articles on scientific and policy matters. He was an advisor on conservation to the United Nations and served a six-year term on the Wisconsin Conservation Commission, a tenure that was dominated by debates over deer policy.

"Leopold advocated restraint more than preservation," said Todd. "He understood that all living things change their environment to survive. He enjoyed hunting, fishing, and cutting firewood (before the chainsaw was invented), and like his father, loved camping, canoeing, and backpacking. But he also witnessed the world changing from one big wilderness with a few people to a populated and developed world with little wilderness. He knew that without wild places, we would never understand the effect of alterations made by our human activities."

During the 1940s Leopold planned a volume of ecological essays, which he titled "Great Possessions." In December 1948, the revised book manuscript was accepted by Oxford University Press. Not long after this, on April 21, 1948, Leopold had a heart attack and died while helping to fight a grass fire on a neighbor's farm. The book, with the final editing overseen by his son, Luna B. Leopold, was published as *A Sand County Almanac and Sketches Here and There.*

Leopold dedicated his book to his wife Estella. Part I of the work uses verbal sketches throughout the months of the year to tell "what my family sees and does at its week-end refuge from too much modernity: 'the shack.' On this sand farm in Wisconsin, first worn out and then abandoned by our bigger-and-better society, we try to rebuild, with shovel and axe, what we are losing elsewhere."

In one sketch, Leopold compared sawing through a large fallen oak to reading history. "We sensed that these two piles

of sawdust were something more than wood: that they were the integrated transect of a century; that our saw was biting its way, stroke by stroke, decade by decade, into the chronology of a lifetime, written in concentric annual rings of good oak."

The ideas developed by Leopold continue to influence forestry, wildlife, wilderness and natural resource management, as well as environmental ethics and environmental literature. One of Leopold's criticisms of the way science addresses ecological questions—that it is too compartmentalized—is being addressed today by the emergence of interdisciplinary studies and approaches that consider systems and regions.

For more about Leopold, visit the Aldo Leopold Foundation website at www.aldoleopold.org. The foundation furnished the Leopold photographs for this story, and the biographical information in this article was adapted from an online chronology of Leopold's life.

Aldo Leopold, center, at the shack with a group of students, probably in 1947, the year before his death.
—PHOTOGRAPH COURTESY OF THE ALDO LEOPOLD FOUNDATION ARCHIVES

Leopold on the Land Ethic

The last chapter of *A Sand County Almanac* redefined the relationship between humankind and the earth. It described a groundbreaking concept Leopold called a "land ethic." This notion has inspired millions to protect our environment, and countless more to live more lightly on the land.

Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher 'standard of living' is worth its cost in things natural, wild, and free. For us of the minority, the opportunity to see geese is more important than television, and the chance to find a pasque-flower is a right as inalienable as free speech. [vii]

That land is a community is a basic concept of ecology, but that land is to be loved and respected is an extension of ethics. That land yields a cultural harvest is a fact long known, but latterly often forgotten. These essays will attempt to weld these three concepts. [viii]

There is as yet no ethic dealing with man's relation to land and to the animals and plants which grow upon it. Land, like Odysseus' slave-girls, is still property. The land-relation is still strictly economic, entailing privileges but not obligations. [203]

We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect. There is no other way for land to survive the impact of mechanized man, nor for us to reap from it the ethical harvest it is capable, under science, of contributing to culture. [viii]

All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in the community, but his ethics prompt him also to co-operate (perhaps in order that there may be a place to compete for). The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land. [203]

A land ethic, then, reflects the existence of an ecological conscience, and this in turn reflects a conviction of individual responsibility for the health of the land. Health is the capacity of the land for self-renewal. Conservation is our effort to understand and preserve this capacity. [221]

It is inconceivable to me that an ethical relation to land can exist without love, respect, and admiration for land, and a high regard for its value. By value, I of course mean something far broader than mere economic value; I mean value in the philosophical sense. [223]

One basic weakness in a conservation system based wholly on economic motives is that most members of the land community have no economic value. Wildflowers and songbirds are examples. Of the 22,000 higher plants and animals native to Wisconsin, it is doubtful whether more than 5 percent can be sold, fed, eaten, or otherwise put to economic use. Yet these creatures are members of the biotic community, and if (as I believe) its stability depends on its integrity, they are entitled to continuance. [210]

The 'key log' which must be moved to release the evolutionary process for an ethic is simply this: quit thinking about decent land-use as solely an economic problem. Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise. [224]

Nothing could be more salutary at this stage than a little healthy contempt for a plethora of material blessings. Perhaps such a shift in values can be achieved by reappraising things unnatural, tame, and confined in terms of things natural, wild, and free. [ix]

Leopold's enduring legacy stems from his prodigious talent in both the sciences and the humanities. He was able to bridge these two cultures by presenting scientific information in narrative form, making ecology accessible to a broad audience in the story form. To highlight the differences between science as narrative and science as reported in a technical journal, seminar students were asked to choose one of Leopold's lyrical essays and rewrite it as a scientific paper. As shown below, Jimmy Fox chose the essay "Draba" and rewrote it as a natural history article.

Draba

Aldo Leopold

Draba verna
—PHOTOGRAPH BY THAYNE TUASON (HTTP://WWW.CWNP.ORG)

Within a few weeks now Draba, the smallest flower that blows, will sprinkle every sandy place with small blooms.

He who hopes for spring with upturned eye never sees so small a thing as Draba. He who despairs of spring with downcast eye steps on it, unknowing. He who searches for spring with his knees in the mud finds it, in abundance.

Draba asks, and gets, but scant allowance of warmth and comfort; it subsists on the leavings of unwanted time and space. Botany books give it two or three lines, but never a plate or portrait. Sand too poor and sun too weak for bigger, better blooms are good enough for Draba. After all it is no spring flower, but only a postscript to a hope.

Draba plucks no heartstrings. Its perfume, if there is any, is lost in the gusty winds. Its color is plain white. Its leaves wear a sensible woolly coat. Nothing eats it; it is too small. No poets sing of it. Some botanist once gave it a Latin name, and then forgot it. Altogether it is of no importance—just a small creature that does a small job quickly and well.

The Life History of *Draba verna*

James L. Fox

ABSTRACT: In North America, Spring whitlow grass, *Draba verna*, is of unknown economic or biological value. The Eurasian herb measures 2.54 to 12.70 centimeters, flowers in early spring and completes its life cycle shortly after seed dispersal. Unlike other members of Division Magnoliophyta, this flowering plant is seldom seen or understood by many *Homo sapiens.*

Key words: Flowers, Plants, Life history, Spring whitlow grass, *Draba*.

Typically, humans are drawn to plants for aesthetic or economic reasons. Some species of the plant kingdom are particularly well understood because of detrimental impacts they have upon other plants, animals, ecosystems or even humans. Due to these concerns, scientists have studied many facets of a plant from its flowering dates to chromosomal structure. However, there are still thousands of species of plants that are poorly understood. They represent either newly discovered plant species, or members of the plant kingdom that are of no pressing interest. *Draba verna* is a member of the latter group.

Life History

Being an introduced species from Europe, this member of Family *Brassicaceae* is distributed on soils with pH 3.6 to 4.3. Mesic to semi-xeric soil types such as those on the glacial drift areas located in Sauk County, Wisconsin, appear to provide *Draba verna* with suitable habitat. This dicotyledon blooms from 25 March to 15 April, emitting little or no odor during the 14 to 21 days of flowering. Structure of the flower is composite, measuring 2.0 millimeters across, and white in color. The stamens are yellow, and the pistils green with sepals absent. Leaves are green, ovate, 15 to 25 millimeters, and encapsulated in fine white hairs. Arrangement of the leaves is rosette in pattern, and located in the basal region. Seed dispersal is accomplished by winds reaching 35 kilometers and upwards. Germination typically occurs from late February to early March for this annual. Senescence begins in late April or early May with plant structure dessication and disappearance happening in summer. Research has not revealed that *Draba verna* gives value to mid-latitude ecosystems and inhabitants, or has noxious effects upon the environment. Spring whitlow grass, as it is commonly called, appears to co-exist quietly in areas not supportive of most plant life. Information on this herb is scarce, and comprises basic structure, phenology, habitat, distribution, and photographs. Although the author could find no information to confirm that this species performs ecological functions in a quantitative or qualitative manner, a review of *A Sand County Almanac* indicates otherwise.

Literature Cited

Leopold, A. 1949. *A Sand County Almanac and Sketches Here and There.* New York: Oxford University Press.

What Is a Weed?

An Essay in Imitation of Aldo Leopold's Essay, "What is a Weed?

Marion Avrilyn Jones

Three summers ago, my husband and I were doing yard work on our front lawn when several male neighbors of ours walked over to visit. Since they usually only come over for an annual autumn bonfire, we knew something was up. My husband quit what he was doing, and quickly asked, "Is everything okay?"

The men glanced at each other uncomfortably. Finally, one of them said, "Well, uh, Dixon, hmm, uh, we were just wondering what you were doing." Sensing this was a serious Between Men moment, I quietly kept working, and moved to a safe distance. Then I looked up. I really looked. At our front yard. So did Dixon. Our eyes met. We burst out laughing. Our manly neighbors looked even more uncomfortable.

The "problem" was this. We had covered our entire once-respectable lawn with a huge tarp, cutting holes only for our Siberian pea shrubs, a few still-tiny lilacs and a lone mountain ash we'd planted in honor of our daughter, Rowan. Dixon stopped laughing and calmly replied, "We're getting rid of dandelions."

At first, the men were too flabbergasted to respond. Then the spokesman tried again, "Oh. Yeah. Um. I've got some stuff you can use for that if you want."

"No thanks, Larry," Dixon answered, "I appreciate the offer, but we want to do it this way." He went back to pruning the pea shrubs. I think he may have whistled, but I may be making up that part.

Finally, one of the other men blurted out, "But yer killin' the grass this way!"

"I know. That's the plan," Dix told him.

They gazed at him blankly, clearly at a loss. Dixon decided to show some mercy. "Well," he explained, "Marion read in one of her organic gardening books that the best way to get rid of dandelions for good is to cover them up for an entire season."

This seemed to help them. It was a Woman's idea; they were used to that themselves. I could see them all breathing sighs of relief that their women, whatever their flaws, were not this batty. On familiar turf at last, they gave Dixon commiseratory glances, and then persisted, "Um. The grass?"

"Well, Marion wants a cottage garden." He gave them a fake hang-dog look, and he was a Buddyboy again. I should have cringed, but since he was telling the gospel truth, I just smiled my best Southern-born smile, kept planting flowerboxes, and asked ever-so-sweetly, "Y'all want some iced tea?

They politely declined. Their mission accomplished, they mozied home to their own little missuz. What they didn't know was that if it hadn't been for them, I would have been perfectly happy with a fieldful of undefeatable soft yellow beauty every summer. Well, for them, and for a friend of mine who, hearing me wax rhapsodic over the aesthetic and medicinal merits of the much-maligned dandelion, had shouted dramatically, "Dandelions?! I get rid of them every chance I get! They're the imperialists of the plant kingdom! They destroy everything in their path! They crush the indigenous population! Diversity doesn't stand a chance when they show up!"

I'd never thought of it that way before. I thought of Denali National Park. She was probably right, as usual. When summer came, we tried the tarp. When the next summer came, there were no dandelions. And no grass either, I could hear my neighbors tisk-tisking under their breaths. We seeded native wildflowers. By June, tiny flowers appeared, and by August, the lawn was ablaze with them. It will be this summer, too. I call it The Neglected Garden. Maybe I'll write a book.

So far, the dandelions confine themselves to our neighbor's lawns, where they look bold and lovely in all that careful green. Maybe they are imperialists, but they are also a reminder of what we can't tame. And maybe they aren't the enemy: as I write this, I sip a cup of Detox Yogi Tea. Its main ingredient is organic dandelion.

PHOTOGRAPH BY SCOTT BAUER, COURTESY USDA AGRICULTURAL RESEARCH SERVICE

Pinus torreyana *ssp.* torreyana. *Torrey pine.*
—© 2002 Tony Morosco

Leopold on Trees

These selections appear in *A Sand County Almanac*.

The pine's new year begins in May, when the terminal bud becomes 'the candle.' Whoever coined that name for the new growth had subtlety in his soul. [p. 82]

Each species of pine has its own constitution, which prescribes the term of office for needles appropriate to its way of life. Thus the white pine retains its needles for a year and a half; the red and jackpines for two years and a half. Incoming needles take office in June, and outgoing needles write farewell addresses in October. [p. 87]

When one pine shows a short year but his neighbors do not, you may safely interpolate some purely local or individual adversity: a fire scar, a gnawing meadowmouse, a windburn, or some local bottleneck in that dark laboratory we call the soil. [p. 83]

The tamaracks change from green to yellow when the first frosts have brought woodcock, fox sparrows, and juncos out of the north. Troops of robins are stripping the last white berries from the dogwood thickets, leaving the empty stems as a pink haze against the hill. The creekside alders have shed their leaves, exposing here and there an eyeful of holly. Brambles are aglow, lighting your footsteps grouseward. [p. 55]

References

Leopold, A. 1949. *A Sand County Almanac and Sketches Here and There*. New York: Oxford University Press.

Leopold, L. B., ed. 1953. *Round River: From the Journals of Aldo Leopold*. New York: Oxford University Press.

Lorbiecki, M. Internet interview found at <forestry.miningco.com>, 4/11/03.

Lorbiecki, M. 1996. *Aldo Leopold: A Fierce Green Fire*. Helena: Falcon Publishing Co.

Further Reading

Armstrong, J. 1995. Keepers of the Earth, in: *Ecopsychology*, T. Rozak, ed. San Francisco: Sierra Club Books, pp. 316–324.

Arnhart, L. 2000. Aldo Leopold's Human Ecology, in: *Conservation Reconsidered*, C. Rubin, ed. New York: Roman and Littlefield. pp. 103–132.

Black Elk, through John Neihardt, *Black Elk Speaks*. 1932. Lincoln: University of Nebraska Press.

Bruchac, J. 2001. The Circle is the Way to See, in: *The Norton Anthology of Nature Writing*. R. Finch, J. Elder, eds. New York: W. W. Norton & Co. pp. 811–818.

Callicott, J. B. 1994. American Indian Land Wisdom, in: *Earth's Insights: A Multicultural Survey of Ecological Ethics*. Berkeley: University of California Press.

Callicott, J. B., ed. 1987. *Companion to A Sand County Almanac: Interpretive and Critical Essays*. Madison: University of Wisconsin Press.

Callicott, J. B. 1989. *In Defense of the Land: Essays in Environmental Philosophy*. Albany: State University of New York.

Callicott, J. B. 1989. A Critical Examination of 'Another Look at Leopold's Land Ethic.' *Journal of Forestry*. 96(1) 20–27.

Callicott, J. B. 1999. Do Deconstructive Ecology and Sociobiology Undermine Leopold's Land Ethic? in: *Beyond the Land Ethic*, Albany: State University of New York. pp. 117–142.

Callicott, J. B. and Freyfogle, E., eds. 1999. *Aldo Leopold: For the Health of the Land*. Washington, DC: Island Press/Shearwater Books.

Flader, Susan L. 1974. *Thinking Like A Mountain: Aldo Leopold and the Evolution of an Ecological Attitude Toward Deer, Wolves and Forests*. Columbia: University of Missouri Press.

Flader, Susan and Callicot, J. B., eds. 1991. *The River of the Mother of God and Other Essays by Aldo Leopold*. Madison: University of Wisconsin Press.

Heffernan, J. 1982. The Land Ethic: A Critical Appraisal, in: *Environmental Ethics* 4 (1982) 235.

Leopold, Aldo. 1933. *Game Management*. Charles Scribner's Sons. Reprinted in 1986 by University of Wisconsin Press, Madison.

Mann, C. C., 2002. 1491, in: *The Atlantic Monthly*, March, 2002.

Meine, C. 1988. *Aldo Leopold, His Life and Work*. University of Wisconsin Press, Madison.

Meine, C. and Knight, R. L., eds. 1999. *The Essential Aldo Leopold*. Madison: University of Wisconsin Press.

Pickett and Ostfeld, 1995. The Shifting Paradigm in Ecology, in: *A New Century for Natural Resource Management*. Covelo: Island Press. pp. 261–278.

Pinkham, J. 1998. The Nez Perce Land Ethic, in: *Wilderness*, Winter 1998, pp. 14–17.

Zeide, B. 1998 Another Look at Leopold's Land Ethic, *Journal of Forestry*. 96 (1) 13–20.

the wolf control issue

Student society hosts moderated discussion

Deirdre Helfferich and Susan Todd

—photograph courtesy U.S. Fish and Wildlife Service, National Image Library

The student Resource Management Society organized and hosted a successful public forum on wolf control at the UAF campus on April 12, 2003. In their introduction of the event, Joe Tatar and Justin Epting, society members, outlined some of the major issues. "Wolves are a resource, but they are also symbolic," Epting said. "To some they represent a wild landscape where top predators still roam freely, but to others they represent competition for valuable game…. We know that wolves, along with bears, can take up to eighty percent of newborn calves in some regions. We also know, however, that Alaska wouldn't retain its wild character and rugged appeal without a healthy wolf population."

Epting briefly described the decades of debate, legislation, and the growing public opposition to wolf control. "Like so many natural resource management issues, the issue is beyond science. Science might help us make a decision, but without considering social acceptance and economic feasibility, that decision may not be the one that is the most beneficial."

The discussion featured a panel of speakers: Pete Buist (representing trappers' interests), Mike Smith (Tanana Chiefs Conference), Patrick Valkenburg (Alaska Department of Fish & Game), and Julie Maier (former vice chair of the Board of Game). Susan Todd of SNRAS stepped in as moderator on short notice, and, said Dave Valentine, a faculty advisor for the society, "her friendly style helped maintain an atmosphere of civil discourse in what has often been a contentious area."

The panel members had varied backgrounds. Pete Buist has trapped for more than thirty years, and his primary trapline is on the Tanana Flats, where intensive wolf control measures were conducted in the 1970s. He was a founding member of the Alaska Trappers' Association, and currently serves on the Alaska Board of Game. He has degrees in forestry and in biology.

Julie Maier is a research associate and affiliate professor with the Institute of Arctic Biology at the University of Alaska, and recently completed a term of more than two years on the Board of Game, during which she was appointed vice chair. Her PhD research was on caribou, but since then her work has focused on moose.

Mike Smith, who grew up in Alaska, has a history of subsistence hunting, fishing, trapping, and subsistence advocacy. He was educated in political science at the University of Alaska, and is currently working as the Wildlife and Parks Program coordinator for the Tanana Chiefs Conference. TCC represents forty-two interior villages, encompassing an area the size of Texas.

Pat Valkenburg is a research biologist who has published over sixty technical reports, scientific papers, and popular articles on caribou, moose, wolves, and predator/prey relationships. He has worked for the Alaska Department of Fish & Game since 1977, primarily studying caribou, but also wolves and moose. He has been directly involved with wolf control programs for the last twenty-five years, in both fieldwork and planning, and is currently research coordinator at ADF&G in Fairbanks. He has a masters in wildlife management from the University of Alaska.

The panelists addressed a list of questions prepared by Dr. Todd and the Resource Management Society students. The questions asked covered the population status of moose, habitat effects on population, the importance and environmental and economic impacts of hunting, predation by wolves and bears on moose, how wolf control is defined and when

Gray wolf.
—John and Karen Hollingsworth, courtesy U.S. Fish and Wildlife Service, National Image Library

or if it should be used, wolf population status in Alaska and elsewhere, the long-term effects of wolf control, and ecological and economic consequences of wolf control (both negative and positive). After the panelists addressed a particular topic, they answered questions from the audience, which numbered about sixty people. After the discussion, David Valentine said, "To me, this was a great example of what our school and our students can do to provide educational opportunities for all interested in contentious natural resource issues."

panel discussion summary

Susan Todd

Moose populations in the Interior

The panel members were in agreement that moose populations throughout Alaska's interior occur naturally at low densities of about one moose per square mile. This, combined with high rates of wolf and bear predation, leaves little surplus for human hunters. In general, humans take three to five percent of a moose population, while wolves, bears, and other predators take ten to twenty-five percent. On average, rural villages require 1.5 moose per household for subsistence purposes, and in some areas of the state it is difficult to meet this demand without reducing predators.

The panel agreed that the habitat in the McGrath area, for example, is capable of supporting more moose. Biologist Pat Valkenburg said that one indicator of good habitat condition there is that thirty to sixty percent of cow moose are producing twins in the McGrath area. A second indicator is the level of browse eaten. ADF&G conducted moose browse surveys near McGrath in 2001 and 2003. These indicated that roughly twenty percent of available browse was eaten. By comparison, moose in the Tanana Flats and Alaska Range foothills south of Fairbanks, consume an average of forty-two percent of the available browse, and the twinning rate averages just six percent.

Mike Smith of Tanana Chiefs Conference talked about the cultural and economic importance of hunting in rural communities. The panelists concurred that current hunting pressure has a low impact compared to predation. Julie Maier observed that the bull:cow ratio is depressed due to selective hunting of bulls.

The panelists agreed that wolves have a significant impact on the moose population in the McGrath area. Valkenburg said that a wolf pack in interior Alaska take an average of one moose per week year round.

Panelists Buist and Valkenburg agreed that bears are also significant predators, particularly on newborn calves, but bears reproduce much more slowly than wolves.

A species' breeding potential is a function of minimum breeding age and number of young per year. Wolves can breed by the age of one year, though they generally breed in the second year and every year thereafter. Most female wolves older than one year become pregnant each year, but usually only the alpha (dominant) female can support her pups. Two-year-

old wolves generally disperse to form new packs. When prey animals are abundant or particularly vulnerable, multiple litters can survive. Wolf litters average six to eight young, a breeding potential just below that of squirrels, rabbits, and housecats, and considerably higher than that of white-tailed deer. Grizzlies and black bears, on the other hand, do not breed until at least three years of age and thereafter breed every other or every third year (black bears), or every three to four years (grizzly bears), with an average litter of only two cubs. Wolves reproduce rapidly and have the potential to recover quickly after a control program, if a food supply is available, while bears do not. Bears are also much easier to hunt than wolves, so bear populations can be controlled through regular hunting. Maier said that bear hunting is not a traditional activity in the McGrath area, and local people should be encouraged to harvest more bears.

What is the status of wolf populations?

Pat Valkenburg explained that worldwide, wolf populations are in excellent condition in Alaska, Siberia, and Canada, and wolf numbers are increasing rapidly in Europe, where wolves are even seen in cities such as Vienna, Munich, and Grenoble. In the Lower 48 states, there are healthy wolf populations in Minnesota, Wisconsin, and Michigan. Since their reintroduction into Yellowstone, the population of 70 wolves has expanded to 700—a tenfold increase in one decade. They are expanding into the western states and may soon be removed from the endangered species list in several areas.

He added that wolves are not endangered in Alaska, where the wolf population varies between 7,000 and 15,000 depending on climate and food supply. Because the federal government has jurisdiction over sixty-five percent of Alaska's land and wolf control is unlikely to occur on federal land, Valkenburg feels it is unlikely that wolves would ever be extirpated from Alaska.

Valkenburg said that people are often surprised to learn that the largest wolf control program in the U.S. is not in Alaska, but in Minnesota, where an average of 150–200 wolves are taken every year by agency personnel to keep the population down. "That is almost twice as many wolves as Alaska has taken in any given control program since 1960," he said.

According to Valkenburg, world-renowned wolf biologist Dr. David Mech feels that the biggest threat to the continued existence of wolves is a lack of regular control programs. "Most people are aware that without some hunting, deer populations skyrocket," Valkenburg said. "Since wolves are much harder to hunt and have even higher breeding potential than deer, they can increase even faster."

Panelist Mike Smith added that once wolves have repopulated their former territory in the West and people have more experience around the animals, realize how adaptable they are and how fast their populations can increase, perhaps there will be less concern about controlling wolves on a small scale in Alaska.

What is wolf control and how does it differ from wolf hunting?

Valkenburg said that the ADF&G uses the term *wolf control* to mean extraordinary methods taken to reduce the fall wolf population of an area by at least fifty percent so that it is below natural levels. This is done using various techniques, such as aerial shooting, land-and-shoot, and sterilization, often combined with an increased trapping effort and relocation of animals.

Buist noted that normal hunting and trapping is rarely adequate to reduce wolf populations in the Interior. "They're smart and they're fast," he said. "They're very difficult to trap and almost impossible to hunt on the ground in forested terrain." In his work as a hunting guide, he said his clients have taken wolves only twice in thirty years, and although he is an experienced trapper, he rarely takes more than one wolf each winter.

Julie Maier added that on the North Slope and other open areas, local people hunt wolves from snow machines and control the populations that way. "Although this is illegal," she said, "people do it and agencies turn a blind eye to it. That's why you don't hear the agencies calling for wolf control on the tundra."

Under what circumstances, if any, is it acceptable to consider controlling wolf populations?

One end of the public opinion spectrum is adamant that wolf control is never acceptable under any circumstances. For example, in 1993, when I began my research on the wolf management issue, Priscilla Feral of the national group Friends of Animals, told the *Fairbanks Daily News-Miner,* "Biologically, it may make more sense [to shoot wolves from the air], but it's like saying: What's the best way to kill a kindergarten class?" (Cole 1994).

None of the panelists would have agreed with Feral. However, their opinions differed. Pat Valkenburg was neutral on this question, which he feels is a social, not a biological, issue. "It's up to the public to make that decision," he said. "Once they make it, then biologists can say how to carry it out in the most efficient and effective manner." For Smith, wolf control is reasonable, if local people require meat for their subsistence needs and if habitat and/or bears are not limiting the moose population. Pete Buist does not see a problem in controlling wolves to benefit subsistence as well as sport and trophy hunters, as the latter groups contribute to the state and local economies. Julie Maier felt that wolf control should be conducted only as a matter of last resort in cases where wolves, not bears, are clearly limiting the prey population, the habitat is in good condition, and subsistence needs are not being met. She does not support wolf control to benefit sport or trophy hunters.

Two hours were not enough time to get through all the questions, but we hoped that people were given a good introduction to the complexities involved. The wolf control issue is a good example of how questions of sustainability are interdisciplinary ones, involving ecology, economics, culture, and philosophy. For more on this idea, see the article on the regional resilience and adaptation graduate training program on page 26.

cooperative research and knowledge transfer at snras

Subarctic Agricultural Research Unit Reestablished

The federal Agricultural Research Service (ARS) has reestablished an Alaska unit based at the School of Natural Resources and Agricultural Sciences. The new Subarctic Agricultural Research Unit will work on projects to enhance the productivity, profitability, and environmental quality of Alaska's farming industry and natural resources. Because ARS scientists are affiliated with the school, with opportunities to cooperate and coordinate research efforts, the association is expected to be mutually beneficial. ARS previously operated an Alaska unit that was closed in the mid 1980s.

ARS, the principal in-house research agency of the U.S. Department of Agriculture (USDA), is charged with extending scientific knowledge through research projects and technology transfer in agriculture, nutrition, technology, and the environment. Alberto Pantoja, entomologist and research leader for the new unit, comes to Alaska from the University of Puerto Rico, Mayaguez, where he was associate dean for research at the Agricultural Experiment Station. He said that although ARS scientists won't teach regular UAF classes, as affiliate faculty they will share their expertise at seminars, conferences, and as graduate committee members.

Canada wildrye, Elymus canadensis *L. The Alaska Plant Materials Center in Palmer conserves seeds and other genetic materials, such as from this species.* —PHOTO BY ROBERT MOHLENBROCK. USDA SCS. 1989. *MIDWEST WETLAND FLORA: FIELD OFFICE ILLUSTRATED GUIDE TO PLANT SPECIES.* MIDWEST NATIONAL TECHNICAL CENTER, LINCOLN, NE. COURTESY OF USDA NRCS WETLAND SCIENCE INSTITUTE.

Research is focused in three main areas: integrated pest management (IPM), food technology and fish byproducts, and plant germ plasm. Current ARS staff members in Fairbanks are: Alberto Pantoja; John Clark, administrative officer; Dennis Fielding, research entomologist; Jeff Conn, research agronomist in weeds management; Peter Bechtel, research food technologist; and Sultan Begna, post-doctorate in entomology. Located at Palmer, Alaska, are horticulturist and curator, David Ianson; plant pathologist Nancy Robertson; and plant physiologist Donald Carling, former SNRAS faculty member. Seven technicians work for the unit: Katherine Beattie, Daniel Labarre, Heather Averett, Kathryn Brown, Kaye Hessinger, Christine Macknicki, and Linda DeFoliart. Pantoja said the ARS unit will recruit researchers to fill two positions for the IPM program and one food technologist for the fish by-products program.

Integrated Pest Management Project

Innovative pest management strategies suitable to northern latitudes support crop and nursery production systems and sustainable natural resources. IPM systems incorporate biologically-based controls, host resistance, cultural control, resistance management, and application technology for the control and suppression of major insect, pathogen, and noxious weed pests that affect field, vegetable and horticultural crops, and rangeland ecosystems. In cooperation with the university, current research conducted by Fielding and Begna aims to develop and evaluate biologically based control systems for grasshoppers. These insects have caused serious agricultural losses in the Delta Junction region, which is a closed ecosystem with great potential for area-wide grasshopper suppression through treatment of a small fraction of its acreage. The pest complex is 85 percent migratory grasshopper, *Melanoplus sanguinipes,* a ubiquitous and mobile species. In Alaska, adults promote reproduction by assembling to bask on south-facing exposures, even subtle ones, where solar irradiation is improved. Major basking areas will be mapped and if necessary modified to improve their basking potential, and new basking areas will be created experimentally to learn how adults may be most efficiently attracted for control. Potential replacements for current control measures will be tested: insecticide baits that use much less toxicant than currently registered sprays, about five percent, and several insect pathogens. Conn and Pantoja are also working on projects under the IPM umbrella. Conn, who specializes in weed management, will investigate the regional invasiveness of weeds and the longevity of seed in soil.

Food Technology

Biochemist and food scientist Peter Bechtel investigates potential uses of fish byproducts. Finding uses for the waste produced during fish processing contributes to industry profitability and environmental protection. Bechtel's research will characterize waste sources and the economics associated with Alaska fish processing, and he is exploring new aquaculture feed ingredients and other products made from these wastes. Waste generated by species, general processing locations, onshore versus factory trawl processing, time of year, amounts of individual waste stream components, and current waste processing and disposal methods will be characterized. Innovative

methods for collecting and storing the wastes will be developed, and components of the waste stream will be used to create a number of new feed ingredients and other products, with processing technologies adapted or developed as needed. The new protein feed ingredients and other products will be chemically characterized (amino acid and fatty acid profiles, mineral and contaminant content, proximate analysis and other analysis) and evaluated for protein digestibility, nutritional value, and palatability.

Whitewater crowfoot, Ranunculus aquatilis *L.* —PHOTO BY WILLIAM & WILMA FOLLETTE. USDA NRCS. 1992. *WESTERN WETLAND FLORA: FIELD OFFICE GUIDE TO PLANT SPECIES.* WEST REGION, SACRAMENTO, CA. COURTESY OF USDA NRCS WETLAND SCIENCE INSTITUTE.

Plant Germ Plasm

The Alaska Plant Materials Center in Palmer, operated by the state Department of Natural Resources Division of Agriculture and funded primarily by the USDA, is one of the twenty-seven sites in the ARS nationwide National Plant Germplasm System (NPGS), a cooperative effort by state, federal, and private organizations to preserve the genetic diversity of plants. The sites conserve seeds and other genetic materials of crops and their wild relatives. Ianson is curator for Alaska's Arctic Genetic Resources Unit, which is a repository for native arctic and subarctic plants—some useful in environmental restoration, some with potential medicinal value—and some grains, legumes, and vegetables adapted to high latitudes. The center develops the plant germ plasm repository; maintains by regeneration or cloning healthy and vigorous germ plasm accessions from other NPGS sites that are better-adapted to Alaska's high latitudes; manages arctic plant germ plasm; conducts research on high-latitude species and agricultural crops related to disease problems or stress adaptation; and coordinates and interacts with Canadian, Russian, Icelandic, and Nordic germ plasm programs. See the NPGS website at The National Germplasm website (www.ars-grin.gov) for more information.

Established in 1953, the ARS is organized to identify problems affecting American agriculture, then plan and execute strategies to address them. These include mobilizing human and financial resources; fostering multidisciplinary research; linking research to program and policy objectives; and communicating and interacting with customers, stakeholders, partners, and beneficiaries to ensure program relevancy. The ARS website is at www.ars.usda.gov or www.usda.gov.

North and West Alaska Cooperative Ecosystem Studies Unit

The University of Alaska has been selected as the host institution for the new North and West Alaska Cooperative Ecosystem Studies Unit (CESU) under the leadership of the UAF School of Natural Resources and Agricultural Sciences and the Agricultural and Forestry Experiment Station. The CESU program is a national network of creative partnerships among federal agencies, universities, and other nonprofit organizations. The collaborations are designed to yield scientific information needed for managing federal resources, while enhancing university research and teaching efforts. Because agencies often must work together to address complex environmental issues that transcend administrative and scientific boundaries, the scope of the CESUs includes the biological, physical, social, and cultural sciences.

Each study unit serves a defined biogeographic area. The North and West Alaska CESU encompasses western Alaska (including the Aleutians), northcentral Alaska (the Interior), and arctic and subarctic Alaska. Southeast Alaska is included in the Pacific Northwest CESU, for which the University of Washington is the host institution; the UA Anchorage (UAA) and Southeast (UAS) campuses are partner institutions in that CESU. "Our CESU will partner with the University of New Hampshire and the Alaska SeaLife Center, and other universities and non-university partnerships are being explored," said Carol Lewis, SNRAS dean, director of AFES, and principal investigator for the CESU project. "Because the host institution for our CESU is the entire University of Alaska, UAA and UAS also are participants in this initiative."

Federal land management, environmental, and research agencies share several science-based goals with universities: high-quality science, usable knowledge for resource managers, responsive technical assistance, continuing education, and cost-effective research programs. "The idea behind the CESU partnerships is that sharing resources and expertise will serve these interests," Lewis said. Participating agencies enjoy the advantage of university resources, which in turn gain financial support and enhanced personnel.

The primary administrative functions of the CESU will be conducted within SNRAS/AFES, with administrative support from several other university entities. Participating federal

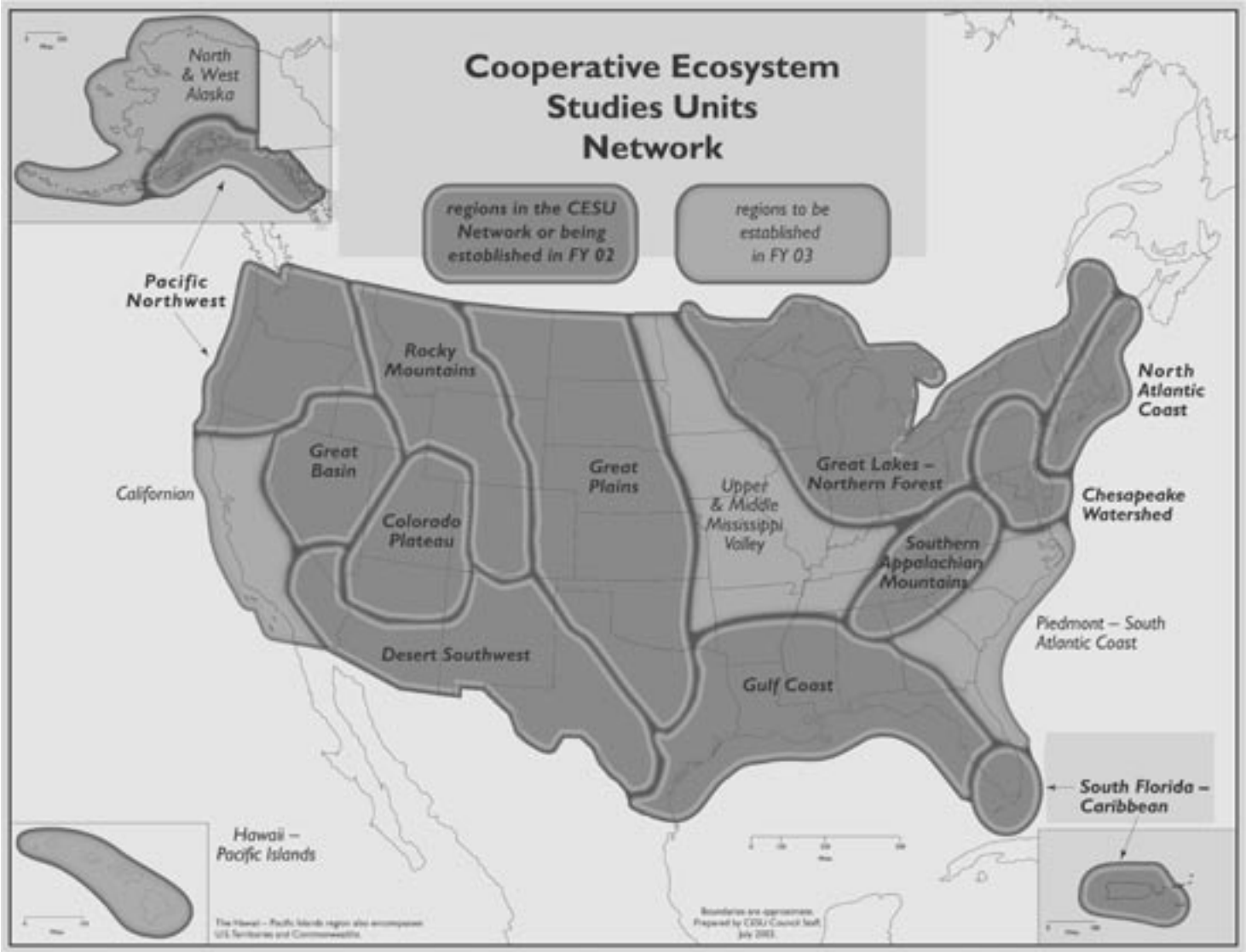
agencies will pay the cost of CESU-affiliated federal employees stationed at the university, and will fund research and program development. As startup development funding, each participating federal agency will provide $10,000 for the Alaska CESU. University cooperators augment their CESU with services and funding as appropriate. Lewis said that as of mid-May five agencies have announced their participation: the Bureau of Land Management, the U.S. Geological Survey (Biological Resources Division), the National Park Service, the USDA Forest Service, and the National Marine Fisheries Service.

The UA CESU proposal was completed by professors Gary Laursen, senior research professor at the UAF Institute of Arctic Biology and Peter Fix, assistant professor of outdoor recreation management at SNRAS. Further support was provided by Craig Dorman, UA vice president for research; Jim Johnson, now UA Vice president for human resources; and Ted DeLaca, UAF vice provost for research. The winning proposal covered the first five years of the North and West Alaska CESU, July 2, 2003 to June 30, 2008.

UA faculty will serve as research investigators, collaborators, reviewers, editors, advisors, and temporary intergovernmental employees. UA undergraduate and graduate students and postdoctoral research associates can assist on projects. Relevant areas of faculty expertise at the doctoral level include arctic, forest, tundra, microbial and physiological ecology; anthropology; archeology; evolutionary theory; cryptogamic botany; fisheries management and biometry; forest soils; geographic information systems (GIS); geomorphology; human dimensions of natural resources; marine plants and mammals; megafauna and megafauna physiology; mycology; natural resource economics; biological, chemical, and fisheries oceanography; ornithology; philosophy; planning; rangeland management; social sciences; soils; and wildlife population dynamics.

Environmental specializations at UA range from environmental contaminants at the elemental level to large landscape- and earth-system science studies. High quality programs are offered across the spectrum of the biological sciences, from leading edge molecular pursuits to taxonomic expertise, to ecosystem-level functioning based on remote-sensing data. The human dimension of ecosystems is represented by strong programs in Alaska Native culture, history, and languages, and in policy-related fields such as natural resource management and economics.

Along with traditional natural resources disciplines such as fisheries management, ocean sciences, wildlife biology and natural resources management, UA has new programs under-



way that can address the needs of contemporary management, such as the Interdisciplinary Graduate Education and Research Training program, (IGERT), which focuses on regional resilience and adaptation (see page 26). The university also is the lead institution for Alaska programs in the Experimental Program to Stimulate Competitive Research (EPSCoR). In the area of interdisciplinary research related to cultural resource management, mutual exchanges between Alaskan indigenous communities and similar ones elsewhere will encourage integrated and interdisciplinary research efforts at UA. Such efforts have traditionally focused on anthropological, archeological, and historical perspectives, as seen in programs aligned with Beringian and coastal arctic tundra investigations. Mutual exchanges are being formed around several other themes related to culture and resources, for example, reindeer-caribou interactions and sustainable communities.

The UA, like its CESU partner institution, the University of New Hampshire, is one of few universities that simultaneously support land-grant, sea-grant, and space-grant missions. Teaching and educational opportunities for federal personnel will be available through several units: SNRAS/AFES and the Cooperative Extension Service, who together pursue the land grant mission in agriculture, forestry, and natural resources management; the Institute of Arctic Biology (IAB), which maintains expertise ranging from molecular genetics to physiology and ecology; the School of Fisheries and Ocean Sciences and the Institute of Marine Science (SFOS/IMS), which promulgates the Sea Grant mission; and the Geophysical Institute, which maintains the UA Space Grant mission.

Natural resource management consists of making and implementing decisions to develop, sustain, and protect natural systems to meet human needs and values. The SNRAS generates knowledge for students and resource users that is important for successful long-term management of land resources in Alaska and the circumpolar world. Since 1948, the experiment station, AFES, has had a formal relationship with the Agricultural Research Service of the U.S. Department of Agriculture, and the broad field of forestry research was further promoted in 1962 by the McIntyre-Stennis Act. Related research covers vegetation, climate change, and ecosystems.

The SNRAS/AFES approach combines elements of the physical, biological, and social sciences. Research at the school investigates relationships of soils to ecosystem function, forest growth, element cycling, and carbon dynamics in the boreal forest. The tree-ring laboratory supports programs in ring-width studies using tree-ring investigation techniques, such as stable isotope analysis and x-ray density studies. The geographic information systems (GIS) lab applies remote sensing data to GIS analysis. The existing program in rural community development is expected to be a fertile source of interdisciplinary projects in such areas as co-management of resources by local residents and local knowledge as it relates to sustainable resource use.

The UAF Institute of Arctic Biology (IAB), which provides undergraduate and graduate training in terrestrial, aquatic, and human biology, is the principal research arm for life scientists at the UAF College of Science, Engineering, and Mathematics. The broad mandate of the institute is the study of the adaptations of microorganisms, plants, and animals, including humans, to cold-dominated climates and environments of the circumpolar arctic and subarctic regions. Studies focus on the physiological adaptations of microbes, plants, and animals (including humans) to past and present climate. This includes population genetics, limnology, wildlife disease, biochemical and molecular biology, neural sciences, and health issues in indigenous or aboriginal populations.

IAB facilitates international, national, and state collaboration with other institutions and agencies, and operates a number of facilities, including two Long-Term Ecological Research (LTER) sites in the Interior (Bonanza and Caribou/Poker Creeks) and one in arctic Alaska at Toolik Lake, where an arctic tundra research laboratory is operated year-round. The IAB core facility for nucleic acid analysis provides molecular analysis in evolutionary biology, and the IAB greenhouse provides climate-controlled growth chambers. The institute also operates the Large Animal Research Station, which provides support for research on animal nutrition, physiology, and behavior.

The Institute of Marine Sciences at UAF carries out research and instruction in marine science and related areas, and is the oldest and the largest component of the UAF School of Fisheries and Ocean Sciences. It is active in research and graduate training, supports coastal facilities at Seward and Kasitsna Bay, Alaska, and operates the 40.5-meter research vessel Alpha Helix for the National Science Foundation. It works closely with the Alaska SeaLife Center, a non-university partner in the new North and West Alaska CESU.

UA's West Coast and Polar Regions Undersea Research Center, housed in the School of Fisheries and Ocean Sciences, was formed in 1990 by the National Oceanic and Atmospheric Administration as part of the National Undersea Research Program. It promotes, facilitates, and supports undersea research along the west coast of the United States and in the polar regions. The school also operates land-based research facilities in Juneau, Kodiak, Seward.

The University of New Hampshire (UNH) brings to the new CESU many programs relevant to the projected work. Faculty expertise includes recreation management and policy, wetlands ecology, forest biometrics and management, soil microbial ecology, natural resource economics, anthropology, environmental economics, community development, water resource economics, terrestrial and aquatic biogeochemistry, land use planning, leisure behavior, geography, and sociology.

Facilities at UNH have capabilities for earth and ocean mapping, bioremediation, water treatment, public policy, and climate change research, among many others. Research facilities include the Institute for Policy and Social Science Research; the Institute for the Study of Earth, Oceans, and Space; the Environmental Research Group, and the Water Resource Research Center. The university also has an Earth

Science Data Distribution System, a digital library of earth science data. The UNH Department of Resource Economics and Development is engaged in discovering new knowledge that will help individuals and organizations responsibly address economic, social, and environmental issues arising from the use and development of natural resources. The natural resources department offers undergraduate and graduate programs in several disciplines, and its faculty is committed to an interdisciplinary approach to natural resource education.

The Alaska SeaLife Center, a non-university CESU partner, is a nonprofit cold-water marine science facility designed to combine a research mission with wildlife rehabilitation and public education. Opened in 1998, it is funded mainly through the Exxon Valdez Oil Spill Settlement Fund. Dedicated to understanding and maintaining the integrity of Alaska's marine ecosystem, the center is in Seward, Alaska, at the head of Resurrection Bay.

Center facilities include modern wet labs, dry labs, in-ground pools, modular bird enclosures, and bird and mammal housing with quarantine capabilities. Veterinary facilities include surgical and necropsy suites, x-ray, and photographic darkrooms. Several marine vessels are available for use in research and there are remote monitoring capabilities at the facility. Graduate training through the University of Alaska is available at the SeaLife Center, and students from other universities also complete work there. The faculty offers expertise in disciplines and interdisciplinary work relevant to federal agencies: marine mammal biology and physiology; pinniped physiology and bioenergetics; veterinary medicine; sea bird ecology and disease; satellite telemetry and physiological data recorder technology; marine species of fish, mammals, cephalopods, invertebrates, and birds; and endangered animal species endocrinology, physiology and behavior.

An early agenda item of the North and West Alaska CESU will be to determine needs of participating federal agencies for the development of a long-range strategic plan and the necessary institutional collaborations, including the western and northern Alaska Native associations and regional corporations, private and corporate research units, educational satellites, elements of the UA system, support facilities, and the many agencies distributed over the three physiographical areas of the CESU.

The multi-agency competition through which a CESU is established is managed by the national CESU Council, which has a website at: www.cesu.org/cesu.

Regional Resilience and Adaptation

Interdisciplinary Graduate Studies

Can the desirable features of both the environment and society be sustained? An innovative graduate program at UAF, Regional Resilience and Adaptation (RR&A), integrates several disciplines to address the question of sustainability. It is part of a national effort to produce new models for graduate learning, the Integrative Graduate Education and Research Traineeship (IGERT) program of the National Science Foundation. Nationwide, universities are awarded IGERT funding based on a competitive proposal process.

At UAF, RR&A trains scholars, policy makers, and managers to address regional sustainability issues in an integrated fashion, preparing students to respond to the major challenge of sustaining ecosystems and society at a time of rapid change in areas that shape their structure and functioning. Based on existing graduate programs in ecology, resource management, economics, anthropology, and philosophy, the program involves faculty from many disciplines, including those in the School of Natural Resources and Agricultural Sciences. The project director and principal investigator is F. Stuart (Terry) Chapin, professor of ecology at the Institute of Arctic Biology (IAB). Gary Kofinas, research assistant professor at IAB, is the RR&A program coordinator. Current co-principal investigators are Rosamond Naylor, David McGuire, Joshua Greenburg, and Richard Caufield. Numerous UAF faculty are actively involved, as are collaborating researchers from other universities, members of indigenous communities, and managers in state and federal resource agencies.

Studies in regional resilience and adaptation are based on two ideas: that major problems facing the world must be addressed at the regional scale and that any tenable solution is ecologically, economically, and culturally sustainable. The interdisciplinary program emphasizes ecology, economics, and culture, three critical factors for understanding interactions between people and their biotic environment in a regional system. Studies in climate dynamics are included, because of climate's importance as a driver of current and future changes. Philosophy provides tools for understanding the ethical issues related to solving ecological and social problems and applying science to management, and for recognizing normative bias as issues of resilience and adaptability are addressed. Communication across disciplines and with local communities, managers, and policy makers requires a sensitivity to, and respect for, different world views. Understanding a regional system well requires the integration of these disciplines.

Some important RR&A program elements are:

• interdisciplinary training (a disciplinary strength with training in other natural and social sciences);

• hands-on research experience in a field outside the student's main discipline, and cross-disciplinary experience

gained during a semester or summer internship in an area other than the major discipline;

• numerous interdisciplinary research opportunities.

The program aims to produce graduates who are well-grounded in one or more disciplines, with knowledge and research experience in a range of natural and social sciences. Students can pursue PhD programs in biology and wildlife, anthropology, marine sciences, and interdisciplinary studies. At the master's level, programs are available in biology and wildlife, natural resources management, marine sciences, economics, political science, northern studies, and interdisciplinary studies. Students receive their degree in the academic department that represents their disciplinary strength, but they also take the RR&A core training program. Students enrolled in PhD programs at other universities also may apply to the RR&A program to spend a year in residence for the interdisciplinary core training.

Research opportunities in the RR&A program involve four interrelated themes: fire regime, forest management, fisheries, and wildlife and subsistence resources. These represent UA research strengths and also some of the most high-profile policy issues in Alaska—issues identified by state and federal management agencies as the most difficult to address. Although students are encouraged to focus their research in one of these four areas, they may participate in other interdisciplinary research efforts when this is more appropriate to their PhD programs.

Because public debate on these highly interdependent issues reveals apparent conflicts between ecological, economic, and cultural values, these areas of concern should be integrated into any potential solution. For example, fire regime strongly influences forest management and vice versa. Fire also is a key management tool used to maximize subsistence resources, and fire control provides wages that enable some indigenous people to remain in villages and participate in subsistence activities.

While no existing program provides full interdisciplinary breadth, the spectrum of UAF research provides a range of disciplinary perspectives on each of the focal themes. Projects in which the students may become involved are carried out by various research units and departments throughout the research community. The programs provide two opportunities for students: they can engage in the research to learn disciplinary skills (the internship program), and they can contribute an interdisciplinary perspective that can broaden the goals of the currently funded research. For example, a student in economics could study fire effects on ecosystem services in the Long-Term Ecological Research (LTER) program, drawing on data and information on ecological processes from the current research and bringing in an economic perspective that would make the LTER research more relevant to society.

Several research programs address the basic ecological processes, management, and economic factors influencing human use of Alaska's boreal forests. The LTER program provides a systems framework to integrate these approaches, and the forestry research programs are closely integrated with the fire research programs in terms of both personnel and the focus on a whole-system approach. Nationwide, the LTER Network is a collaboration of many scientists and students investigating ecological processes over long temporal and broad spatial scales. It was established in 1980 by NSF to support research on long-term ecological phenomena in the United States, where there are now twenty-four LTER sites representing diverse ecosystems and research emphases.

The central question in the Bonanza Creek LTER program concerns how the Alaska boreal forest responds to changes in climate and the disturbance regime (fire, flood, harvest). The overall objective is to document major controls over forest dynamics, biogeochemistry, and disturbance, and, in the context of climate change, how they interact. Research is organized around the themes of forest dynamics, the changing boreal carbon cycle, and regional and landscape controls over disturbance regime. As a focus for integration and synthesis, three topics have been identified that cut across all themes: species effects on ecosystem and landscape processes (how species identity and diversity influence biogeochemistry and disturbance regime); spatio-temporal scaling to provide the conceptual basis for linking process and pattern; and ecosystem sustainability to explore how the positive and negative feedbacks that operate within ecosystems influence the sensitivity of ecosystems to perturbations such as changes in climate and disturbance regime. Visit www.lter.uaf.edu for details.

Research related to fire regime uses observations, field experiments, and systems modeling to examine the short- and long-term effects of fire on ecosystem processes and their interaction with regional and global climate systems. Researchers are studying the role of land-cover change in the high-latitude ecosystem, the implications of land-cover change for regional and global carbon dynamics, and the role of fire in global carbon balance. Other research recently implemented considers on a regional scale the economic and societal consequences of a changing fire regime and human effects on the fire regime. "Frostfire: the Role of Fire in Permafrost Terrain in the Boreal Forest," is an experimental study of fire feedbacks to climate. Also related to fire regime are research on the role of humans and on lightning from thunderstorms, the dominant fire-starting mechanism for large wildfires in interior Alaska.

Several studies related to forest management address the basic ecological processes, management, and economic factors influencing human use of Alaska boreal forests. The research includes the LTER program studies, Boreal Ecology Cooperative Research Unit work, and study of alternative forest harvest strategies. The Boreal Ecology unit, part of the USDA Forest Service Pacific Northwest Research Station, conducts cooperative research programs on the ecology of interior and northern Alaska. Unit members are stationed at the university and also function as faculty members for graduate education and training. The unit focuses on analysis of landscape patterns in interior Alaska. Unit scientists are involved in many of the research programs described here and their participation

offers RR&A students an opportunity to be involved with Forest Service programs and projects and to understand how agency researchers interact with managers and policy makers.

Alternative forest harvest practices are the subject of two long-term studies. A study begun in 1972 at a typical upland white spruce site has shown that after twenty-seven years, overstory treatment had no effect on the density or growth of any species, whereas scarification greatly increased the density of white spruce seedlings and saplings, although even unscarified areas had sufficient regeneration to produce a fully stocked stand. In the second study, two different levels of partial overstory retention are being compared with clear-cut harvesting on a productive floodplain site, following an initial harvest in 1983. Researchers are examining the effect of these overstory treatments on forest regeneration, soil thermal regime, and the fate of coarse woody debris. This research provides opportunities for numerous ecological studies on the consequences of alternative harvest treatments.

The ecological, economic, and anthropological components of wildlife and subsistence research also employ various approaches, including systems modeling. The LTER program is documenting the long-term population dynamics of small mammals (microtine rodents, snowshoe hares, and (in collaboration with the Alaska Department of Fish and Game) moose. Also under study are the effects of animals on ecosystem processes. This is accomplished by using exclosures to keep animals out of specified areas, then documenting interannual and spatial variations. Included in the study are the effects of animals on plant production, plant composition, and biogeochemical processes.

A project on the ecology and economics of the moose-forest interaction examines how moose function in interior forests and how they directly and indirectly affect vegetation dynamics, other wildlife species, and human social and economic experience. The project compares three disturbance types (flooding, fire, and forest harvest) that create and maintain the habitat of moose and other wildlife. Studied as disturbance responses are moose abundance and distribution; the moose herbivory; plant population dynamics; and hunter effort and success rate. This work aims to consider the diverse ecological functions of moose in interior forests, how forestry practices may affect these functions, and how moose management objectives affect moose population dynamics and human interactions with this natural resource.

The ecological, economic, and cultural dimensions of reindeer-caribou interactions in western Alaska also under study. The research addresses the cultural and economic role of reindeer herding in the indigenous communities in western Alaska, as well as the economic and ecological ramifications of the massive influx of caribou from the Western Arctic Caribou Herd onto the region's reindeer ranges. The project aims to increase understanding of the feedbacks between climate, environment, and human land use in the Arctic. Field-based research and modeling activities are used to address research objectives.

The sustainability of arctic communities is the subject of an eight-year collaboration between researchers and local knowledge holders. This new approach to regional integrated assessment is based on interdisciplinary science and local knowledge concerning environmental change and human adaptations to it. The first four years involved twenty-three researchers representing eight natural and social science disciplines and four partner communities. The study examined how the combined effects of climate change, oil development, tourism, and government cutbacks might change the sustainability of arctic villages. The study's second phase aims to develop and test integrated assessment methods by focusing on the combined effects of climate and petroleum development on sustainability. Visit www.taiga.net/sustain for details.

Research on regional impacts of North Slope bowhead whale hunting employs home production theory and regional input-output modeling. Subsistence activities, whaling in particular, are difficult for contemporary researchers to evaluate or to quantify in a format understandable in western culture. Working in partnership with the North Slope Borough Department of Wildlife Management and the Barrow community, researchers are addressing the need for comprehensive economic methodologies that depict the non-formal subsistence sectors of rural Alaskan economies.

The RR&A program begins with an intensive year of coursework that enables students to address regional issues from various perspectives. Subsequent years emphasize the application of this understanding to teaching and research. The first-year program consists of orientation on Alaska's regional issues, interdisciplinary core courses, as well as courses and research experience outside the student's main discipline. Other coursework provides graduate-level background in the processes that govern ecological, economic, and cultural sustainability and acquaints students with the ethical and philosophical issues required to communicate among disciplines and across cultures.

Participating SNRAS faculty are Cary de Wit (cultural geography, sense of place), Glenn Juday (plant community ecology; paleoecology; reserve design), Scott Rupp (forestry, landscape and fire-vegetation-climate modeling), David Valentine (forest soils, ecosystem ecology, carbon and nutrient cycling), Joshua Greenberg (resource economics, effects of resource policy change), and Carol Lewis (resource economics).

For more information, visit www.regional-resilience.uaf.edu, the Regional Resilience and Adaptation website.

—cooperative research articles by Doreen Fitzgerald, staff writer

RR&A Faculty Participants

Biology and Resource Management

Richard Boone: Microbial ecology; soil responses to global change
Terry Bowyer: Wildlife biology; behavioral ecology
F. Stuart (Terry) Chapin, III: RR&A project director; ecosystem ecology; climate-vegetation-fire interactions
Cary de Wit: Cultural geography; sense of place
Glenn Juday: Plant community ecology; paleoecology; reserve design
Knut Kielland: Ecosystem ecology; role of vertebrates in ecosystem processes; nutrient cycling
Anthony David McGuire: Ecosystem, regional and global modeling
Eric Rexstad: Population biology of small mammals; wildlife management
Scott Rupp: Landscape modeling; fire-vegetation-climate modeling
Anthony Starfield (Univ. of Minnesota): Modeling ecological systems and their interactions with humans
David Valentine: Ecosystem ecology; carbon and nutrient cycling; soils
Marilyn Walker: Landscape dynamics and plant community diversity
Tricia Wurtz: Forest regeneration and management

Atmospheric Sciences

Amanda Lynch (Univ. of Colorado): Climate modeling; influence of land-surface properties on regional climate

Economics and Political Science

Henry Cole: Systems modeling; environmental policy
Joshua Greenberg: Resource economics; impacts of changing resource policy
Mark Herrmann: Fisheries economics
Judith Kleinfeld: Role of culture in learning; gender issues
Jack Kruse (Univ. of Massachusetts): Interactions of social and natural sciences as these relate to indigenous peoples
Carol Lewis: Resource economics
Rosamond Naylor (Stanford University): economic and policy dimensions of land-use change; valuation of ecosystem services

Anthropology

Richard Caulfield: Traditional ecological knowledge and practice in relation to subsistence and resource management
Craig Gerlach: Archaeology of northern peoples as hunter-gatherers
Patricia Kwachka: Anthropology of northern peoples
Phyllis Morrow: Resource co-management and cross-cultural interactions involving Alaska indigenous peoples
William Schneider: Oral traditions of Alaskan indigenous peoples

Philosophy

Michael Jennings: Comparative philosophy of indigenous peoples and western thought as a basis for governance and resource management
Eduardo Wilner: Philosophy of science, research, and bioethics

2002/2003 snras graduates and senior theses

degrees earned

Geography

Adams, Mark Edward, B.A.
Barry, Sean, B.A.
DeGering, Tracy Teal, B.S., Environmental Studies
Lewanski, Marya Katherine, B.A.
O'Connor, Yvette, B.S., Environmental Studies
Pistor, Daniel, B.S., Environmental Studies
Saltzman, Kyle, B.A.
Storm, Jared, B.S., Environmental Studies
Wiskeman, Robert Bryan, B.A.

Natural Resources Management

Banducci, Allegra, B.S., Resources
Collins, Andre Emanuel, B.S., Forestry
Dusenbury, Matthew, B.S., ?
Liljeblad, Adam J., B.S., Resources
Massie, Tammy M., B.S., Plant, Animal, and Soil Sciences
Milne, David, B.S., Resources
Oleson, Heather Jeanne, M.S.
Smith, Glenda J., B.S., Plant, Animal, and Soil Sciences
True, Nicholas A., B.S., Forestry
Vogt, Susan L., M.S.
Walt, Alexander J., B.S., Forestry

snras senior theses

Andre Collins

Impact of trembling aspen and paper birch overstory competition on early height growth of planted white spruce in interior Alaska.

Allegra Banducci

Influence of public interest groups on oil pipeline development.

Matthew Dusenbury

Groundwater dynamics under air sparging system, former building 1144 on Fort Wainwright, Alaska.

Tammy Massie

Winter range selection by individual caribou in reference to herd location: site fidelity versus herd fidelity.

Permafrost and Ponds

Remote sensing and GIS used to monitor Alaska wetlands at the landscape level

Doreen Fitzgerald with Brian A. Riordan

To address the question of how observed climate warming has affected Alaska's wetlands, graduate student Brian Riordan is using digital images obtained during the past fifty years to study ten sites in three regions of the state—areas with no permafrost, discontinuous permafrost, and continuous permafrost (Figure 1). The study, begun last year, is restricted to closed-basin water bodies having have no direct influx or outflow of stream water. His preliminary results show that in areas of discontinuous permafrost, the area of closed-basin water bodies has significantly decreased during these decades.

"Hydrologic systems are intricately related to the entire ecosystem in which they exist," Riordan said. "My research is designed to locate water body loss, observe its extent, and if possible, determine whether climate warming is a leading factor in the reduction of water volume at the observed sites."

The research plan requires Riordan to establish the weather history and analyze remote sensing images of each site. The images he's working with are

- From the 1950s, black and white aerial photographs and digital raster graphics (DRGs), which are scanned 7.5 minute topographic maps;
- From 1978 to 1982, color aerial infra-red photographs;
- From 1985 to 1995, Landsat TM satellite images;
- From 1999 to 2001, Landsat-7 ETM+ satellite images.

To determine the number and size of closed-basin ponds and lakes during these periods, Riordan is using Geographic information system (GIS) technology, which makes it possible to correlate and compare the images. Collectively, a GIS is an organized set of computer hardware, software, geographic data, and personnel used to capture, store, update, manipulate, analyze and display forms of geographically referenced information. A GIS makes it possible to perform complex spatial operations that would otherwise be very difficult, time-consuming, or impractical. Riordan's major professor is David Verbyla, who teaches GIS techniques and analysis and is particularly interested in using the technology for resource inventory and climate change studies.

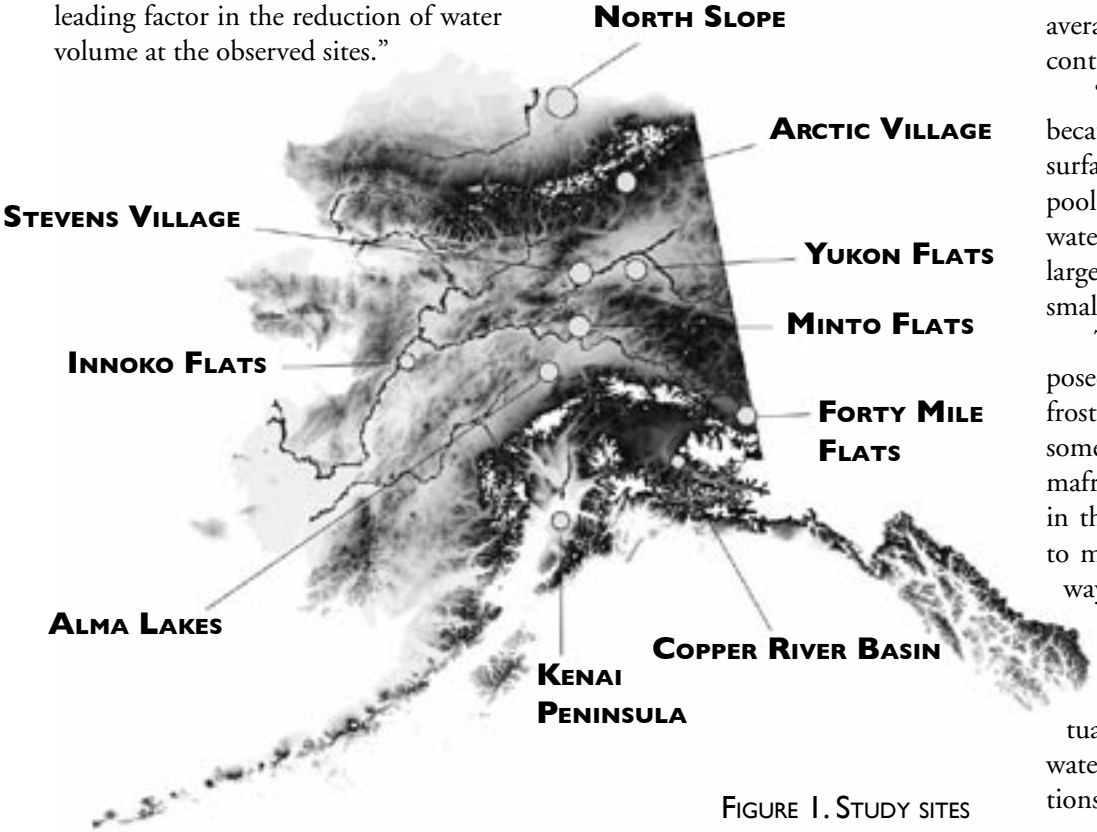


Figure 1. Study sites

Permafrost Ponds

Permafrost, ground that remains at a temperature below 0°C for a period of two years or more, incorporates about twenty to twenty-five percent of the earth's land surface and approximately seventy-five percent of Alaska's land surface. Permafrost is characterized as either continuous or discontinuous, based on its location, thickness, and average temperature—factors usually controlled by latitude.

"Many of Alaska's wetlands exist because permafrost holds water on the surface," Riordan said. "It tends to cause pooling of near-surface ground water, or water from melting snow, which creates large tracts of land covered with many small ponds and lakes."

There are two mechanisms proposed to explain how thawing permafrost causes the loss of these wetlands. In some cases, the underlying layer of permafrost acts as a liner that retains water in the pond. If climate warms enough to melt the permafrost, the layer gives way, allowing the pond to drain into the underlying gravel. This runoff presumably flows into the water table, the river systems, and eventually the sea. A large input of fresh water from this source has ramifications for seawater salinity and sea levels.

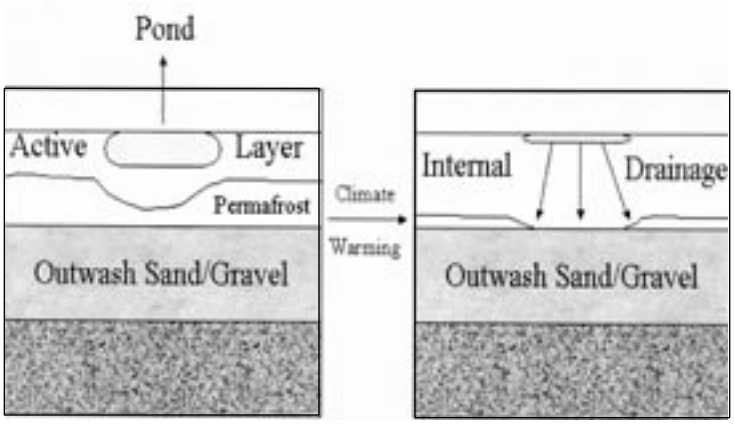


FIGURE 2. As warming occurs the permafrost layer begins to degrade until it fully thaws. Thus any water it retained drains into the underlying media.

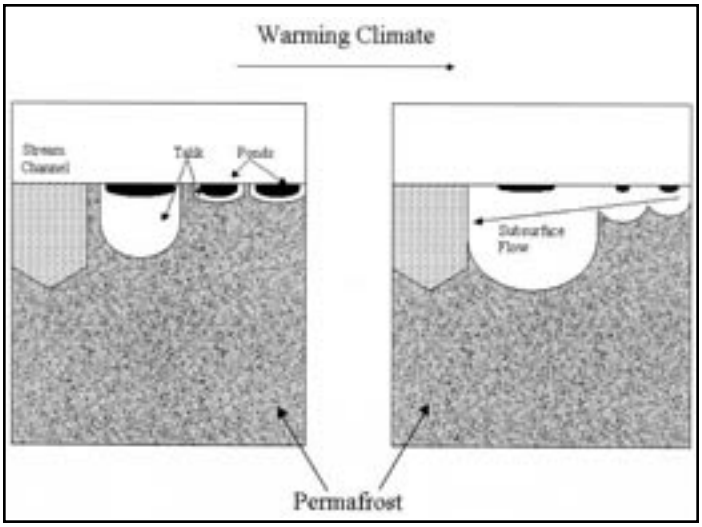


FIGURE 3. Enlargement of the talik layer, resulting in subsurface drainage above the permafrost layer.

The diagram in Figure 2 illustrates this drainage mechanism.

The second mechanism is similar, but explains how drainage can occur in the presence of permafrost. Talik is the unfrozen soil between discontinuous blocks of frozen soil or between the permafrost table and the bottom of the active layer. When the talik undergoes warming, the permafrost below it begins to thaw and recede, enlarging the talik layer. As taliks grow and merge, a subsurface drainage is created above the permafrost layer. This subsurface flow then drains diagonally into adjacent streams or other water bodies. Figure 3 shows how warming can affect taliks and thaw ponds.

Continuous permafrost in the arctic ecosystem reaches a thicknesses of up to 640 meters on the North Slope. The discontinuous permafrost usually found in subarctic regions, where temperatures are warmer, range in thickness from 30 meters in Fairbanks to just a few tenths of a centimeter at the southern limits of the permafrost region (Committee on Permafrost 1983). Because the discontinuous permafrost layer is so thin, southern regions of Alaska are one of the first areas to show signs of permafrost degradation. Recent studies by Tom Osterkamp and Vladimir Romanovski of the UAF Geophysical Institute and others have documented the warming and thawing of this discontinuous permafrost. Mean yearly temperatures in regions of discontinuous permafrost are generally greater than -5°C, and the temperature of soils in these areas has risen 0.5°C to 1.5°C from the 1980s to the 1990s (Osterkamp and Romanovski, 1999).

Riordan has hypothesized that in areas of discontinuous permafrost, a significant decrease in water body acreage has occurred since the 1950s. He expects that a climactic warming shift that occurred in the late 1970s may have resulted in permafrost melting in these regions, and that this shift has allowed internal drainage of closed-basin ponds through the permafrost into glacial outwash sand and gravel. For comparison, his study includes areas of continuous permafrost on the North Slope. There Riordan predicted that the loss of closed-basin ponds or lakes would be insignificant, because of the thickness of the permafrost layer and the mean annual temperature.

The sites in his preliminary study are in the areas of the Copper River Basin, Yukon Flats, and the North Slope. One of Riordan's first tasks was to obtain weather records for each site to establish that temperatures did indeed warm up during the decades covered by his study. The available weather data for each area is shown in Figure 4, Graphs 1, 2, and 3. Because of the state's size, remoteness, and low population density, Alaska has few reliable weather stations that date back more than thirty years. The most reliable weather station on the North Slope is at Barrow, which is 200 miles from the North Slope study site. The Copper River basin site is 30 miles from the Gulkana weather station. Bettles, the weather station for Yukon Flats, is more than 150 miles from the study site.

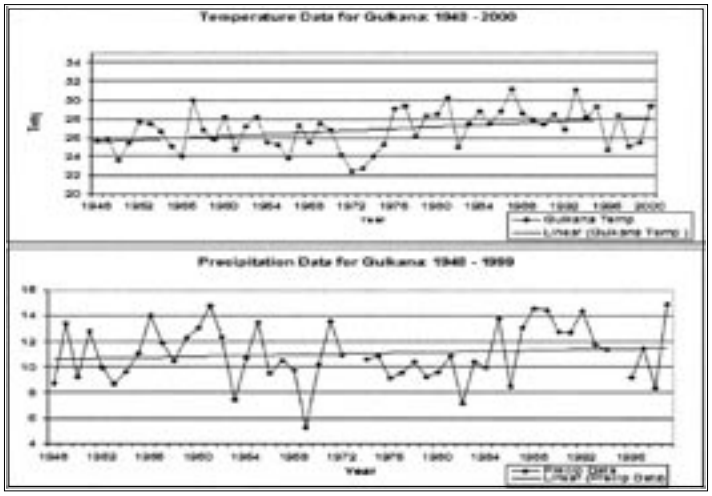
Study Sites and Weather

At Gulkana, where reliable weather records date back to 1942, the mean annual temperature has increased 2.94°F since 1971, as shown in Graph 1. At this station, annual precipitation has increased more than one-half inch since 1948. "Although the precipitation change is nominal compared to the temperature increase, it remains relevant, because even with the increase in precipitation, we have recorded a decrease in water volume," Riordan said. "Without the increased evaporation and transpiration associated with climate warming, you'd expect increased precipitation to be associated with increased water volume." In the entire state, there has been a thirty percent increase in precipitation from 1960 to 1990 (National Assessment Synthesis Team, 2000).

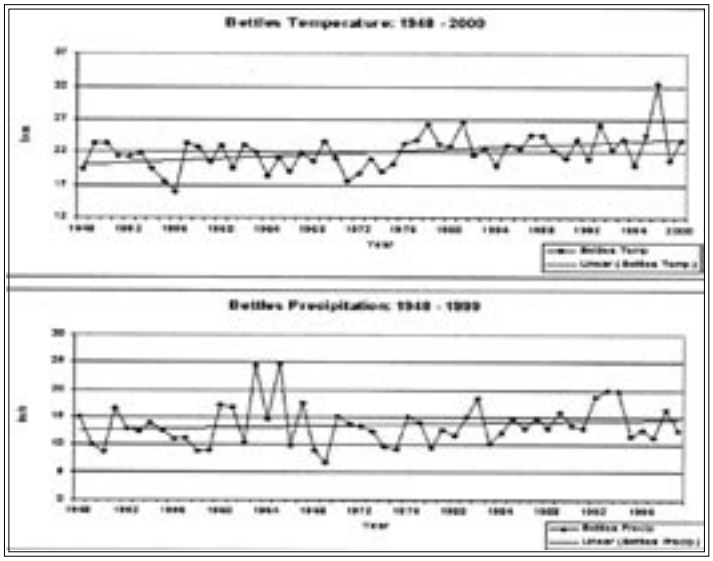
The Bettles weather station has recorded weather since 1944, and the data appears sound. Since 1971, the mean annual temperature has increased of 3.61°F. Since 1943, the mean precipita-

Figure 4. Temperature & Precipitation at Three Study Sites
The top chart of each pair in these three weather graphs represents temperature in °F by year, and the bottom chart shows precipitation in inches by year for each site. The fitted line shows an increase in both over the fifty-year time frame.

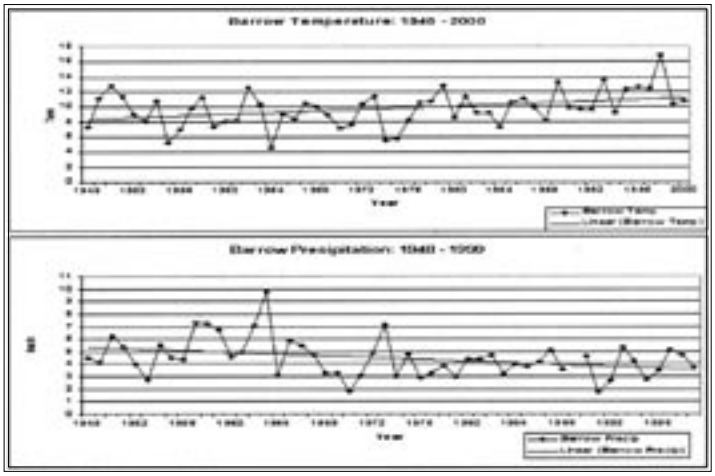
Graph 1: Copper River Basin Weather
data taken from Gulkana Airport.



Graph 2: Yukon Flats Weather
data taken from Bettles



Graph 3: North Slope Weather
data taken from Barrow



tion has increased two inches (Graph 2). The records at Barrow date back to 1921. Since 1971, the station has recorded a mean temperature increase of 4.16°F. Since 1948, mean precipitation has decreased more than 1.5 inches (Graph 3).

To supplement this weather data, Riordan hopes to include in his study a simple evapotranspiration model. "This will help show changes in the monthly evapotranspiration from 1940 to 2001," he said. "It also will help demonstrate climate change and spread out the dependence on average temperature. To make sure the images I've obtained are not from days of abnormal weather, I also need to obtain the daily records for many of these sites."

Near the town of Gulkana, the Copper River Basin study site is on the southern edge of the discontinuous permafrost zone. "I expected this to be one of the first area to show pronounced effects of permafrost degradation in its closed-basin water bodies," Riordan said. The Yukon Flats study site is in the center of the Yukon Flats Wildlife Refuge, where the closest town is Fort Yukon. The area, also is underlain by discontinuous permafrost, has thousands of small ponds and is home to a diverse waterfowl population. However, since it is at a higher latitude with cooler temperatures, Riordan predicted less permafrost degradation and water body loss than in the Copper River Basin. On the Arctic Coastal Plain near Prudhoe Bay, the North Slope study site contains thousands of thaw ponds underlain by continuous permafrost. Because mean temperature there is well below freezing, Riordan predicted he would find that closed-basin water bodies would have remained intact and relatively unchanged during the past fifty years.

GIS and Images

For any geographical area, a GIS can present information in layers of logically separated mapped data. In this case, Riordan is layering the information from images taken decades apart to compare the number and size of the water bodies. Layers are all registered to one another by means of a common coordinate system. A layer usually represents a theme, such as roads or water bodies, which is a user-defined perspective on a geographic dataset. The theme contains features such as points, lines, or polygons.

The GIS technology can be used to clarify and refine geographic data. For example, Riordan isn't interested in open-basin water bodies (those having inflows and outflows of water), so he can simplify his images by removing them. Riordan's GIS methods are yielding one water body theme corresponding to each year for which an image is available. In the case of Copper River Basin there are four water-body-theme shape files: 1957, 1985, 1995, 2001. Each of the newly created water body themes has its own associated attribute table. Using ArcView, Riordan can create a new column for each polygon that calculates the acres for each water body. By using the summarize function, he then can obtain the total number of water bodies present and their acreage.

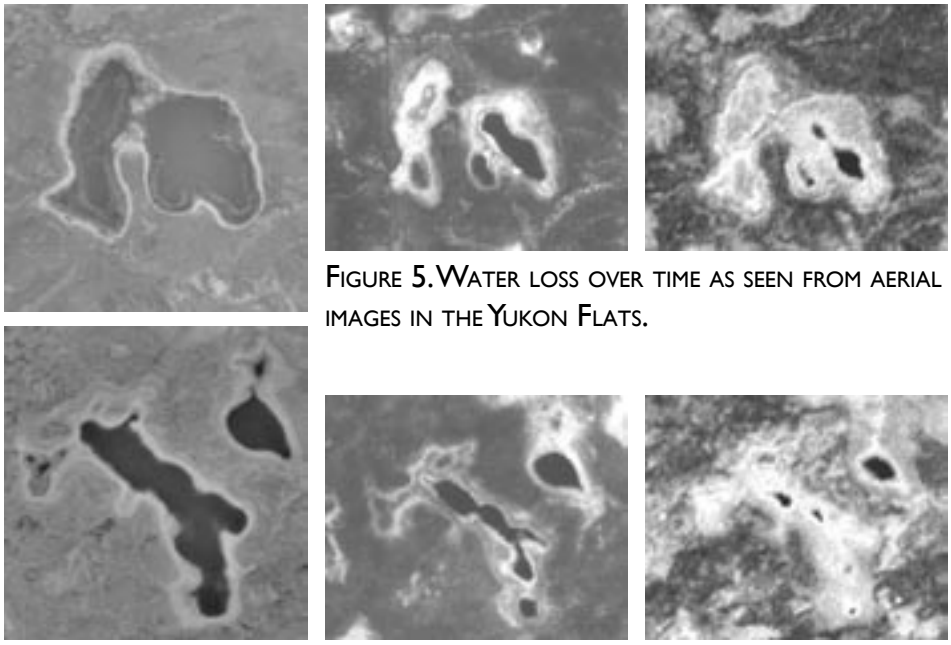


FIGURE 5. WATER LOSS OVER TIME AS SEEN FROM AERIAL IMAGES IN THE YUKON FLATS.

From left to right, upper row.
Left: Black & white aerial photo from the 1950s.
Middle: Orthophoto from 1980.
Right: Landsat ETM + Pancromatic Band, August 16, 2000.

In these images the dark colored regions represent water. The two sets of images are of lakes located in the same region, about seven miles from each other. They are both excellent examples of the large-scale water body loss that is being observed across much of Alaska.

From left to right, lower row.
Left: Black & white aerial photo from the 1950s.
Middle: Orthophoto from 1980.
Right: Landsat ETM + Pancromatic Band, August 16, 2000.

For each location, Riordan wanted a minimum of three to four images, each separated by about ten to fifteen years. "This provides me with a good representation of changes that have occurred over the fifty-year time span," he said. However, he discovered that for high-latitude regions, it can be challenging to locate high-quality Landsat images with a low amount of cloud, fire, and shadow contamination, some of which is due to increased daylight in summer. "Cloud shadows are of particular concern, because they can create values similar to those of water, and can obscure the terrain. Using Landsat imagery, it's important to account for the cloud and smoke cover in an image."

Riordan acquired Landsat ETM+ imagery for three areas. "To detect change over time, it's necessary to have has many images as possible that were made between the time points. For a few areas, I already have a Landsat image from 1985–1995, but most of the areas have either no image or images with significant cloud cover problems. After examining all the possible paths and rows that could contain a useable image, I've identified at least one image from 1985–1995 that can be used. However, due to the cost of each image, I couldn't include it in this part of the study, but I will use it in the final project."

Through research and experience, Riordan discovered interpretation errors associated with the DRGs, so he is using them only as a tentative outline for the 1950 base. To improve the information, he ordered the original black and white photographs from which USGS quadrangle maps were derived. Because these maps are a fine spatial scale and several sites have over fifty associated photos, covering all ten areas with these aerial photos required more than 200 images.

Riordan recently located and obtained aerial photos for the years between 1978–1981. The originals are at the Map Office at the UAF Geophysical Institute. "I located digital scanner capable of scanning 10x10 transparencies and moved a workstation over to the map office so I could personally scan the original photos onto my computer. I have just finished this aspect of the project."

Riordan is applying many different techniques to the images, so that after GIS processing, each image is in a similar projection and can report water loss in acres. "I ended up using only ERDAS 8.5 and ArcView 3.3 to do all the remote sensing and GIS work," he said. "Each image will be georeferenced to the oldest image present, which for each site is the DRG. This is the one step that all the sites had in common. To incorporate a full study area, as many as four DRGs are required. To keep the files as manageable as possible, I've clipped each image down to the exact area of interest. This area is then used as a mask for all the subsequent Landsat and aerial photographs."

Preliminary Results

To date, Riordan's results generally support his hypothesis that the most water-body loss will be detected in regions of discontinuous permafrost. The most southern site is the Copper River Basin. When he calculated the acres and number of water bodies from the 1957 closed-basin ponds water body theme, there were 59.05 acres and 241 water bodies. The next image, taken thirty years later, showed a 33.4 percent acreage loss and more than half of the water bodies had disappeared. By 1995, the acreage loss was 62.1 percent and the number of water bodies had decreased by more than 80 percent.

"The 2001 Landsat ETM+ image showed a slight recovery from the large losses shown in the 1995 data. Since 1957 there was a 56.5 percent acreage loss, but between 1995 and 2001, there was a 12.9 gain. Although the water body volume during this later period changed only 12.9 percent, the number of ponds increased by 44 percent, to 86 ponds in 2001. However, this is still considerably less that the 242 present in the 1950s."

Because of its higher latitude and colder temperatures, Riordan expected the Yukon Flats site would experience con-

siderably less reduction of acreage and number of water bodies than the Copper River Basin site. There were more losses at Yukon Flat than expected. The starting number of water bodies was 749, about three times as many as at the Copper River Basin site. In 1952 the DRG showed a total of 1156.12 acres, which fell to 656.864 by the 2000 image, a 43.2 percent loss. The number of water bodies fell by only 18.8 percent, but the number lost was 141, which is similar to the 155 lost at the Copper River Basin site.

The North Slope, with its low temperatures and thick permafrost layer, was not expected to experience reductions in either the number of water bodies or their volume. According to the study results, the North Slope site lost less than one percent of the acres of closed-basin water bodies during the study period (from the DRG to the ETM+ images). The change in the number of water bodies is less than six percent (176 of 3,157).

The Copper River Basin site has displayed the largest amount of water loss, while the North Slope has remained stable. The amount of loss in the Yukon Flats is interesting and slightly more than anticipated, which could be caused by factors other than climatic warming. "Even without shape polygons and complicated GIS programs, water body loss is evident," Riordan said. "It can be seen on the ground and by looking at simple aerial photographs. Our ability to process this data using GIS software to obtain outlines of the ponds provides more detailed information about the amount of degradation present."

Results showing large-scale disturbances on areas of discontinuous permafrost, with relatively little disturbance on the North Slope raise other questions. How much of this change is directly related to climate change? How much might be seasonal variability? What about other possible draining events? Are there better methods available to detect climate change than temperature and precipitation?

"We know that discontinuous permafrost can be very volatile and close to thawing. The temperature changes since the 1940s have been at levels greater than what would be needed to thaw many of these areas. The Copper River Basin is a prime example of this. The warming there (more than 2.1°F) has been more than enough to melt the thin discontinuous permafrost within that region."

The Yukon Flats area is also within the discontinuous permafrost zone, but Riordan thinks that vegetation succession, as well as permafrost degradation, may be contributing to the widespread water. "It may be caused by a combination of permafrost degradation and vegetation succession, and both of these events are related to climate change. Having not actually visited these areas, I'm only hypothesizing about the vegetation that might be encroaching on these water bodies."

Analysis of the North Slope site revealed an interesting feature: although the water body acreage remained stable, there was a six percent loss in the number of water bodies. Riordan thinks is the result of ponds merging. "Since there are so many ponds in this area, they occur close together, and it's probably not uncommon for two to merge."

As Riordan edited the digital line graph for each time frame, he found many instances where open water bodies, rather than closed-basin ponds, had drained. They are not included in this study because these changes could be due to vegetation succession or catastrophic drainage via stream or river channel disruption, as well as permafrost thaw. "While it would be hard to pinpoint the reason for the drainage of these open water bodies, it seems important to report that the visual observation of the loss, which appears to equal or exceed that of the closed-basin ponds," he said.

As his research continues, Riordan will address several problems he's encountered. Because it is difficult to acquire cloud-free images in Alaska for periods without snow cover, he is on several sites restricted to only three periods, which increases the chance that results will be influenced by seasonal variations. To address this question and strengthen his results, he is trying to obtain shifted images that might have at least small areas from which to sample the water body population. A shifted image is created by overlapping two images to combine the east (or south) information from one image with the west (or north) information from another image. Images can also be combined on the diagonal.

To further address the question of seasonal variability, he hopes to obtain two images within the same calendar year for as many sites as possible, one in late June and the other in peak thaw period, July 15–Aug 15. This will allow him to detect whether the ponds have permanently drained, or if they fill each year and drain by midsummer. "The more images I can obtain for each site, the more reliable the results become."

After speaking with many people about the digital raster graphic images, it was clear to Riordan that there is a fair amount of user error within them. "To account for this, I needed to acquire the original black and white aerial photographs and run a quality check to obtain a level of confidence. For this purpose I now have over 200 photos that must be scanned, placed into the GIS and given coordinates."

The Warming Trend

Air temperatures around the globe have been slowly rising since the late 1800s, a rate that increased in the late 1900s. In 1977, a significant increase in global air temperature occurred (National Assessment Synthesis Team. 2000). The effects of global warming have been observed and documented throughout the world. For example, the International Arctic Science Committee reported that in Fairbanks, Alaska, the number of days with temperatures reaching -50°C is now half what it was in 1950 (International Arctic Science Committee, 1999).

Some of the many models developed to predict the degree of global warming estimate an increase of 2–3°C as a result of atmospheric trace gases (Jorgenson. et al. 2001). The literature also indicates that the northern latitudes could see temperature changes as high as 4–6°C in the mean annual climate. The larger increase in temperature in northern latitudes would occur because the greenhouse warming effect is amplified in

Aerial view of a wetland landscape in the Innoko National Wildlife Refuge.
—photograph by Leslie Kerr, courtesy of the U.S. Fish and Wildlife Service, National Image Library

the north, primarily due to feedbacks from variations in sea ice and snow. The thawing of permafrost is considered to play an integral role in such cycles (Serreze, et al. 2000).

A recent study on global warming states that "…the most severe environmental stressors in Alaska at present are climate-related." This report identifies four key issues associated with warming in Alaska: these are melting of permafrost and sea ice, increased risk of fire, implications for marine life and fisheries, and stress on tribal life (National Assessment Synthesis Team 2000).

Riordan's research will shed more light on effects related to thawing permafrost and Alaska's warming climate. "Even in nonpermafrost areas, such as the Kenai Peninsula, loss of water bodies over the past twenty years is apparent, and drying can lead to other landscape-level disturbances, such as bark beetle infestations and increased wildfire." said Dave Verbyla, professor of geographic information systems in the UAF forestry department. "This and similar research at the landscape level should continue to be vital for understanding the regional system and the effects of climate change."

The study is funded under NASA's Land Cover Land Use Change Program (LCLUC) and conducted under the direction of Verbyla and David A. McGuire, associate professor in the UAF biology and wildlife department.

References and Further Reading

Committee on Permafrost. 1983. Permafrost Research: An Assessment of Future Needs. Washington, D.C.: National Academy Press. 103 pp.

Davis, Neil. 2001. *Permafrost: A Guide to Frozen Ground in Transition.* University of Alaska Press.

International Arctic Science Committee. 1999. Impacts of Global Climate Change in the Arctic Regions. (April 25–26) Fairbanks, AK: Center for Global Change and Arctic Systems Research. 59 pp.

Jorgenson, M.T., Racine, C.H., Walters, J.C., Osterkamp, T.E. (2001) Permafrost degradation and ecological changes associated with warming climate in central Alaska. *Climatic Change,* 48, 551–579.

National Assessment Synthesis Team, Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change, US Global Change Research Program, 400 Virginia Avenue, SW, Suite 750, Washington DC, 20024.

Osterkamp, T.E., and Romanovski, V.E. (1999). Evidence for Warming and Thawing of Discontinuous Permafrost in Alaska, in: *Permafrost and Periglacial Processes,* 10, 17–37.

Serreze, M.C., Dyurgeroy, M., Romanovski, V.E., Oechel, W.C., Zhang, J.T., Barry, R.G., Walsh, J.E., Chapin, F.S., Osterkamp, T.E. (2000). Observational evidence of recent change in the northern high-latitude environment. *Climatic Change,* 46, 159–207.

Woodin, S.J., Marquis, M. (ed.) 1997. Arctic soils and permafrost. In: *Ecology of Arctic Environments.* Blackwell Science Ltd. p. 1–40.

Wright, R.K. (1981). The Water Balance of a Lichen Tundra Underlain by Permafrost. Montreal, Quebec: Centre for Northern Studies and Research.

School of Natural Resources
and Agricultural Sciences
University of Alaska Fairbanks
P.O. Box 7577200
Fairbanks, AK 99775-7200

Nonprofit
Organization
U.S. POSTAGE
PAID
Permit No. 2
Fairbanks, Alaska

Above: mixed salad greens grown at the Palmer Research and Extension Center. AFES experiments are being conducted on baby greens, head lettuce, and greenhouse production of salad greens.
—PHOTOGRAPH BY ROSANN LEINER

Right: Pansies grwon under artificial light at the AFES greenhouse in Fairbanks.
—PHOTOGRAPH BY JEFF WERNER